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ERRATA

Page 60, line 1 of footnote, for "Gainer" read "Gaines."

Page 62, line 2 of reference 13, for "members" read "numbers."

Page 62, line 2 of reference 15, for "Amerranten" read "Aberranten."

Page 77, paragraph 2, line 5, for "Queensberry" read "Quisenberry."

Page 79, paragraph 3, line 1, for "four" read "three."

Page 79, paragraph 3, line 1, for "XII and XIII" read "and XII."

Page 104, paragraph 2, for the third sentence substitute "Originated by bulking together a number of lines which were selected from the original Marquis, and appeared identical."

Page 110, line 2, for "II" read "2."

Page 179, third figure of left margin, for "15" read "10."

Page 193, line 1 of Book Review, for "Kelner" read "Kelser."

Page 243, paragraph 2, line 16, for "1%" read "61%."

Page 250, paragraph 4, line 5, for "soils" read "soil."

Page 257, table 10, centre section, col. 7, line 2, for "58.1" read "69.3."

Page 257, table 10, lower section, col. 6, line 3, for "16" read "61."

Page 412, paragraph 2, line 4, for "11" read "12."

Page 418, table 3, transpose lines three and four of figures at right of dividing down rule.

Page 567, delete foot note.

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SELF-FERTILIZATION IN RELATION TO FORAGE CROP IMPROVEMENT.*

LAWRENCE E. KNIT†

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INTRODUCTION

Previous to the time of Darwin, interest in plant hybridization centered around the question of the benefits secured to plants by means of cross-fertilization as opposed to self-fertilization. Experiments were largely confined to interspecific or at least relatively wide crosses. The net result of these studies was to show the widespread occurrence of cross-fertilization in nature and the very numerous and highly adapted means by which cross-pollination might take place. Practically all of the early hybridists noted the fact that hybrids frequently possessed a constitutional vigor greatly in excess of that of the parents. Many extended accounts of their observations on this phenomenon were published. However, no adequate explanation of the cause was obtained.

Darwin was the first to investigate the effects of cross-fertilization and self-fertilization in a comprehensive and logical manner. No phase of the subject seems to have escaped his attention. His general method was to compare plants produced from self-fertilized seed with others from cross-fertilized seed of the same parent plant. After the first generation, several flowers on one or more of the self-fertilized plants were again self-fertilized, and several flowers on one or more of the crossed plants were fertilized with pollen from another crossed plant of the same lot. A wide range of species was investigated in this manner and in some cases the study was continued for 10 generations. The plants from selfed and cross-fertilized seed were then compared with respect to height, weight, constitutional vigor and fertility.

The conclusion reached by Darwin was that cross-fertilization is generally beneficial and self-fertilization injurious. The advantages of the former were attributed to the crossing of forms which have been, in some degree, differentiated in their sexual elements; the disadvantage of the latter was regarded as resulting from the lack of such differentiation. Thus the nature of the phenomena was correctly diagnosed as germinal. His con-

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Practically all of the investigations have been carried out on the University of Saskatchewan Field Husbandry experimental plots. The writer wishes to gratefully acknowledge the facilities provided by this institution and the generous cooperation of all members of the Field Husbandry staff.

clusion that germinal differences were due to the plants having been grown under different environmental conditions probably was incorrect. He clearly perceived, however, that this theory did not constitute an explanation of the true nature of the differentiation and he was wholly at a loss to explain many significant observations, as for example, why highly self-fertile varieties sometimes arise from cross-fertilized plants that have been self-fertilized for several generations or why inbreeding possesses certain advantages so far as the fixing of characters is concerned.

The Mendelian conception of heredity which was introduced with the rediscovery of Mendel's publication furnished a new method of attack regarding hybrid vigor and other problems of inheritance. In 1905, East and Shull independently began experiments for the purpose of studying intensively the physiology of inheritance of maize. Their results, which were mutually corroborative, presented a beautiful picture of the workings of hybrid vigor. It was learned that, in maize, inbreeding always leads to a reduction in the yield of seed and the height of plant. In general, the decrease in vigor due to selfing is greatest in the first selfed generation and continues on to a certain point, after which no further decrease can be observed. Both good and bad strains are isolated with definite hereditary morphological characters. Crossing of selfed strains, on the other hand, results in a uniform and vigorous progeny which frequently exceeds the average of the original cross-fertilized plants in this respect.

The methods followed by East and Shull marked a considerable advance in that they compared successive generations of selfed lines descended from the same original plant, under a single set of natural field conditions and in a manner which permitted the taking of comparable yield data. On this account they were able to measure, what Darwin was unable to observe, the relative rate at which reduction in vigor proceeded with successive generations of selfing, as well as the fact that decrease in vigor did not take place indefinitely. From these circumstances and the additional fact that the original vigor could be restored by a single cross between inbred individuals, they disproved the popular conception that inbreeding is inherently harmful and demonstrated that the accumulation of evil effects, mentioned by Darwin, was apparent rather than real.

It remained to explain the variability in vigor of selfed lines and first generation hybrids on a factorial basis, for it was evident that some were much more vigorous than others. East and Hayes proposed the theory of "heterozygosis" which states that hybrid vigor is proportional to the number of factors in which the parents differ. Thus, in their own words, "the decrease in vigor is due to inbreeding naturally cross-fertilized species and the increase in vigor due to crossing naturally self-fertilized species, are manifestations of one phenomenon. This phenomenon is heterozygosis. Crossing produces heterozygosis in all characters by which the parents differ. Inbreeding tends to produce homozygosis automatically."

Although these investigators believed that hybrid vigor was correlated with the heterozygous condition, they apparently thought that some sort of a physiological stimulus resulted from the heterozygous condition. It was not understood why no vigorous selfed lines could be obtained in such a cross-pollinated plant as maize. It should be remembered that at this time

it was not generally recognized that a normal character is dependent upon the interaction of many genetic factors and that there was no adequate knowledge of linkage relations and the chromosome theory of heredity.

A satisfactory and altogether natural hypothesis to account for hybrid vigor was finally evolved from the conceptions underlying heterozygosis, dominance and linkage. This interpretation was proposed by Jones who concluded that heterosis* results from the complementary action of dominant linked growth factors. Since F_1 hybrids will usually possess a larger number of such factors than their parents, the dominance or partial dominance of favorable factors will result in greater development. It is evident that the amount of heterosis in the hybrid will depend on the number and nature of such factors by which the parents differ, and this at once explains why some crosses result in greater hybrid vigor than others and why hybrids that exhibit heterosis invariably produce progeny, when self-fertilized, which show a decrease in vigor of growth.

The chromosome theory of heredity, the facts of linkage, and the view that most normal characters are the result of the interaction of many factors plus environment, are firmly established. The mechanism which underlies the phenomenon of heterosis is generally regarded as satisfactorily explained. An excellent working basis is thus provided for studying the principles which should govern the improvement of crop plants. The procedure for self-fertilized crops already has been standardized, but much remains to be learned of theoretical and practical importance regarding the breeding behavior of cross-pollinated plants. This can best be accomplished by an extension to other crops of the methods which have been used with maize, followed by a critical analysis of the results secured. Even with maize, which has been more intensively investigated than any other plant, much is yet to be learned regarding the best methods for utilizing inbred lines in the production of improved varieties. In recent years the principle of selection within self-fertilized lines has become widely accepted. It is evidently regarded by many plant breeders as a method of improvement which holds great promise for crops which are naturally cross-pollinated.

This paper presents the results of self-fertilization studies with alfalfa, brome grass, and red clover. These crops have commonly been regarded as normally cross-fertilized although it is generally recognized that alfalfa is self-fertilized to some extent. Self-fertilization was studied in relation to vigor of growth, seed production, winter hardiness, and reduction in variability in morphological characters. Seed setting under conditions of controlled pollination has received considerable attention. The occurrence of chlorophyll deficiences and abnormalties has been noted. Methods of procedure, of course, have varied with the crop, as well as the extent and details of the experiments performed. The object and point of view, however, have been the same throughout, namely, to study biologic phenomena associated with self-fertilization, and so far as possible, their genetic interpretation, keeping in mind the implications from a practical plant breeding standpoint.

A brief review of the findings of recent investigators will now be considered, as their results throw considerable light on the effects of inbreeding with widely different kinds of crop plants.

*The term "heterosis" was first used by Shull (27). It has since found general favor as a synonym for hybrid vigor.

Literature Review

Darwin (2) studied the effects of self-fertilization by comparing the plants from self-fertilized and cross-fertilized seed produced by the same individual. Selfing was continued with some of the species for as many as ten generations. A marked difference in height, weight, constitutional vigor, and fertility of the offspring was observed in favor of the plants from crossed seed. These differences were attributed to the injurious effects of self-fertilization inasmuch as the flower structure of some of the species had practically insured cross-fertilization during many generations. He believed that the advantages of cross-fertilization were the direct result of differences in the sexual elements of the parent plants due to environmental influences and not to any mysterious virtue in the mere union of the germ cells of two individuals.

Darwin showed that notwithstanding the evil effects which many plants suffer from self-fertilization, they can be thus propagated under favorable conditions for many generations. He regarded the effects as evil only in the sense that they are disadvantageous and in no way the result of the increase of some morbid tendency or inherent weakness of constitution due to consanguinity. Just as the advantages of cross-fertilization were thought to be due to the differentiation of the sexual elements, so he believed the injury from self-fertilization follows from the want of such differentiation.

Maize has been studied more extensively than any other crop with respect to the effects of self-fertilization and the application of selection within self-fertilized lines as a practical means of producing improved varieties. In 1910, Shull (26) summarized the results of his previous five years' work with maize under 12 headings. A few of his conclusions based on experimental evidence may be restated as follows:

1. The progeny of every self-fertilized corn plant is of inferior size, vigor and productiveness as compared with the progeny of a normally cross-bred plant derived from the same source.
2. The decrease in size and vigor is the greatest in the first selfed generation and becomes less and less in each succeeding generation until a condition is reached in which there appears to be no further loss of vigor.
3. Self-fertilized families from a common origin differ from one another in definite hereditary morphological characters.
4. Regression of fluctuating characters has been observed to take place away from the common mean or average of the several families instead of toward it.
5. A cross between sibs (brother and sister) within a self-fertilized family shows little or no improvement over self-fertilization in the same family.

East and Hayes (3) self-fertilized over 30 varieties of maize for from one to seven years. Their results confirmed those of Shull in every respect. Since these early experiments were reported, many thousands of selfed lines of corn have been grown and an extensive literature has developed on the subject.

All of the main types of corn have been inbred by self-fertilization for several successive generations. In general the results have been the same for

all types. Jones and Mangelsdorf (17) give the history of four selfed lines descending from the Leaming variety which had been inbred for at least seventeen successive generations. After the ninth generation, no further reduction in size and vigor could be observed. These inbred strains were only one-half to one-third as productive as the original variety. They possessed a high degree of uniformity and remained perfectly healthy. Decrease in yield apparently results from a lessening of the rate of growth accompanied by a reduction in size of all parts of the plant.

Thus far it has not been possible to secure selfed lines of corn which are vigorous enough to be used as improved varieties. At present interest is centered in the relative utility of different selfed lines as parental material and the best methods by which they may be recombined.

Many single crosses between selfed lines and double crosses between F_1 hybrids, as well as other composite crosses, have been made. Synthetic varieties, the result of combining several selfed lines, have also been studied. Comprehensive data on the results of crossing selfed lines of corn have been published by Jones and Mangelsdorf (17), Richey and Mayer (25), Kiesselbach (19), Hayes (7), and others. In general, these studies have shown that hybrids may yield above the average of the parental varieties from which selfed lines were obtained, and that some hybrids may be secured which yield appreciably above the original varieties from which the selfed lines were obtained.

One of the striking results of self-fertilization in maize is the appearance of various types of abnormalities. These occur most frequently during the early generations of selfing and include seedlings and mature plants which are wholly or partially lacking in chlorophyll, deformations of stem, foliage and floral parts, variations in leaf colors and markings, sterile ears and tassels, defective endosperms, and aborted seeds. Many of the plants thus affected are automatically eliminated because of the sterility or abnormal physiology. The inheritance of a large number of these characters has been studied and the linkage relation of some 50 factors has been more or less definitely determined. A comprehensive survey of studies in maize inheritance has recently been published by Hayes and Garber (11).

Self-fertility in rye was studied quite extensively by Heribert-Nilsson (12, 13). He obtained 4 per cent. of seed setting using parchment bags, the range for most plants being from 0 to 5 per cent. One or two plants in every hundred showed a high degree of self-fertility. There was reduction in vigor, on the average, up to about the fifth generation. A few strains which had been selfed for nine generations continued vigorous and yielded more than the original cross-pollinated variety. Vigorous selfed lines were used to synthesize an improved variety which has found a useful place on the farms of Sweden.

Brewbaker (1) studied self-fertilization in rye from a number of interesting view points. He obtained considerable reduction in vigor which was most marked in the early generations of selfing. Many weak strains were eliminated during these years. He observed a considerable number of abnormalities, those of most frequent occurrence being white seedlings and a type which was designated as "yellow-green stripe." His data indicate that the majority of inbred plants were highly self-sterile. Strains were

found, however, which appeared to breed true for relatively high as well as low self-fertility, but in general there was much variation in this character from year to year. Differences were also found in rust resistance, color of seed coat, and other characters. Eight selected strains which had been self-fertilized for five generations, yielded on the average as much as the commercial sorts.

Nilsson (24) began breeding sugar beets by controlled pollination at Svalöf, Sweden, in 1914. Many of the lines appeared uniform after one generation of selfing. In general, the selfed lines gave a somewhat lower yield than the standard sorts, but a number of them proved to be as high or higher yielding than the best of the normally cross-pollinated varieties. No further loss in vigor was observed after the fifth generation. In many hundreds of investigated beet and mangel strains, less than 5 per cent showed signs of so-called degeneration. Fertility was plainly inherited and strains which possessed this character had larger and better developed seed.

Studies in the self-fertility of red clover have been carried on by Fergus (4), Kirk (20), and Williams (29). The number of plants in most of the lines have been small because of the difficulty of obtaining self-fertilized seed. Most of the selfed lines were characterized by a marked reduction in vigor. There was much variability in this character, however, and several strains appeared to be quite vigorous after only one or two generations of selfing. Chlorophyll deficiences were found to occur frequently. A number of strains were secured in the fourth generation which appeared to possess a much greater degree of self-fertility than others. Self-fertility in red clover and the effects of inbreeding will be considered in greater detail in connection with the presentation of experimental results.

McRostie (23) and Hamilton (6) have reported work with selfed lines of sunflowers which had been in progress for six or seven years. In general, the effects of inbreeding were similar to the results observed with corn. Most of the strains were considerably reduced in vigor and after five generations of selfing showed a high degree of uniformity in morphological characters. Several strains were obtained which are as vigorous as the varieties from which the selfings were made.

Fruergaard (5) worked with selfed lines of turnips. All of them were less vigorous than the original varieties, being reduced in yield on the average about 30 per cent. In sharp contrast to the results with turnips, rutabaga gave only 2 out of 35 selfed lines which showed any appreciable decrease in yield as a result of selfing. This fact was attributed to the high degree of self-fertilization in this crop.

Kearney (18) artificially self-pollinated cotton for five to seven generations without impairing the vigor or fertility. This result was in keeping with expectation since natural self-pollination occurs in cotton to a much greater extent than cross-pollination.

Hayes and Barker (8) and Hayes and Clark (10) published the results of work with a number of lines of timothy which had been produced by self-fertilization for four or five generations. The results indicate that timothy does not show nearly as much reduction in vigor as corn or red clover. Some of the selfed strains were less vigorous and others more vigorous than the best commercial sorts, but in few of them is the reduction very pro-

nounced. From eleven first-generation selfed lines five gave albino seedlings. Susceptibility and resistance to stem rust of timothy, and also self-fertility under conditions of controlled pollination were shown to be inherited.

Jenkin (16) found that self-sterility in perennial rye grass (*Lolium perenne*) is very pronounced but occasional plants were found which are relatively highly self-fertile. The selfed progeny was uniformly less vigorous than the progeny of cross-fertilized plants. When plants from promising selfed lines were intercrossed, very vigorous F_1 families were sometimes obtained. It was found that certain crosses were more valuable than others but that their ability to produce high yields was not necessarily a reliable index of their desirability as parental material. The statement was made that it would seem possible to eliminate the undesirable plants by a system of intercrossing.

I. SELF-FERTILIZATION STUDIES WITH ALFALFA

Materials and Methods.

The experiments with self-fertilized lines of alfalfa herein reported were preceded by twelve years of intensive selection work in which relatively hardy varieties or regional strains from many sources were used. Winter hardiness, seed production, and productivity, were the characters more especially desired. From some 1,300 plants under observation, 110 selections were propagated as follows for the purpose of studying further the homozygosity and relative productivity of the progeny:

50 plants of each propagated clonally.
50 plants of each propagated from self-fertilized seed.
4 rod rows of each propagated from cross-fertilized seed.

Fourteen of the best strains from this selection project were used as material from which to obtain self-fertilized lines. Twelve selections (I-XII) traced directly back to the original Grimm variety (*Medicago sativa media*), one selection (XIII) traced to a strain which was introduced as *Medicago falcata* but which was obviously a sativa x falcata hybrid, and another (XIV) belonged to a falcata strain designated as Obb which commonly bred true for typical falcata characters.

There was considerable advantage in using the above mentioned material for this experiment. In the first place, it provided superior adapted strains, a circumstance which is highly desirable in a study of this kind. In addition they were selections with which we had become thoroughly familiar. To these advantages may be added that of having 50 clonally propagated plants from each original selection, making several plants with which to work instead of only the one from which the cuttings were made.

From these cuttings was obtained naturally cross-fertilized and first generation selfed seed. As has been mentioned already, plants from first generation selfed seed from each of the selections (except number XIV) were also available, and these became the progenerators of second generation selfed seed. Thus there was available (a) open-fertilized seed from cuttings of the original plants, (b) first generation selfed seed from the same, and (c) second generation selfed seed from several first generation plants of the same parentage.

The method used for artificially self-pollinating the plants was to enclose the flower heads in small Kraft paper bags. From 3 to 5 heads were enclosed in each bag before the flowers had opened. The bags were manipulated with the fingers twice without opening, for the purpose of tripping the flowers. After the pods had set, the bags were torn open and all buds and unfertilized flowers removed. By leaving the torn bags attached to the stems, the heads producing pods with selfed seed could be much more readily recognized. This was an advantage because it was necessary to re-examine all the material two or three times before maturity to remove flower buds which frequently made an appearance on the stem above the point where the bag was tied.

Self-pollinating by the method just described has proved very satisfactory under our conditions. As a rule, considerably less seed is set in the bags than when flowers of the same strain are open-pollinated, but the quantity of seed obtained by selfing in any one season is roughly in proportion to the amount of seed secured from the same strain by open-pollination. This statement applies only to the first generation of self-fertilization.

The seed was planted in the greenhouse in 3-inch pots and the seedlings transplanted into the field about June 1st. This nursery consisted of about 5,000 plants and occupied 1.2 acres. The following diagram (Fig. 1) illustrates the general plan of the breeding nursery as it appeared in the field.

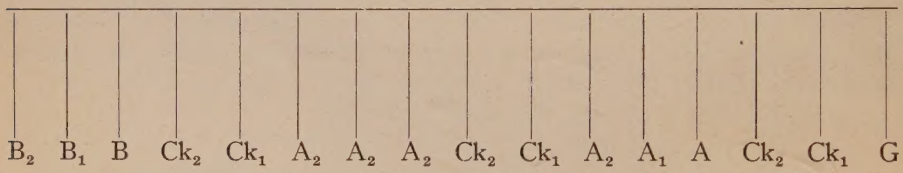

Fig. 1.—Diagram of a portion of the alfalfa breeding nursery. Each line represents a row of 40 plants, each plant spaced 42 inches apart each way.

G=guard; Ck_1=check (Grimm); Ck_2=check (Grimm Sask. 666); A, B, etc.=plants from cross-fertilized seeds of original plant selections; A_1, B_1, etc.=first generation selfed lines; A_2, B_2, etc.=second generation selfed lines. Read right to left.

From Fig. 1 it will be seen that two-thirds of the rows are adjacent to a check and the other rows are only once removed. The double set of checks makes possible a fairly reliable statistical analysis of the yield results. All weighings were made with a Troemer gram scale just as the rows were cut and the weight per plant obtained on the basis of the number of plants harvested.

In 1926, a nursery of third generation selfed lines was planted similar to that described above, consisting of about 3,000 plants. Plants from cross-fertilized seed and first generation selfed lines of the original material were included for comparison. Only one cutting from this nursery has yet been obtained.

Self-Fertilization in Relation to Yield of Forage

Table 1 contains the average yields of first, second, and third generation selfed lines of alfalfa expressed in percentage of the yield of plants from cross-fertilized seed. Table 2 gives the average prcentage yields for all strains in each generation.

TABLE 1.—*Percentage yields of forage of First, Second and Third Generation selfed lines of Alfalfa.*

Strain No.	Cross-fertilized	First generation selfed	Second generation selfed lines		Third generation selfed lines*	
			Mean	Range	Mean	Range
1	100	68	49	43–55	--	-----
II	100	73	95	78–111	66	38–91
III	100	76	61	47–74	34	16–49
IV	100	82	77	74–80	--	-----
V	100	82	87	82–96	27	15–39
VI	100	89	61	50–70	--	-----
VII	100	81	--	-----	--	-----
VIII	100	80	62	61–64	48	28–66
IX	100	88	64	59–69	57	-----
X	100	89	47*	46–47	--	-----
XI	100	95	46*	31–61	--	-----
XII	100	70	72	51–85	64	35–90
XIII	100	89	80	45–118	67	25–100
XIV	100	75	--	-----	--	-----

* The yields of third generation selfed lines and second generation selfed lines for strains X and XI were obtained from one cutting only. All other yields are an average of three cuttings in two years.

TABLE 2.—*Average percentage yields of Alfalfa for all strains in the First, Second, and Third Generations of Selfing.*

Generation	Number of strains	Number of cuttings	Percentage yield	
			Mean	Range
Cross-fertilized	14	3	100	-----
First generation selfed	14	3	81	68–95
Second generation selfed	41	3	72	43–118
Third generation selfed	37	1	53	15–100

Probable errors have been computed on the basis of 24 checks for the average of three cuttings. For the variety Grimm Sask. 666 the probable error was 7.03 per cent. and for the standard Grimm variety 9.49 per cent. The average yield for the two series of checks for all cuttings was approximately the same. When the yields of these two series of checks were correlated, a value of $r=0.74 \pm 0.09$ was obtained, indicating a fairly high degree of correlated variability for adjacent plats. The variability in the yield of check plats in the third generation nursery for the one cutting was much larger, giving a probable error of 15.83 per cent.

From the data presented in tables 1 and 2, it is evident that inbreeding of the alfalfa has resulted in a progressive decrease in vigor of growth. First generation selfed lines are reduced on the average 19 per cent, the loss in yield varying from 5 per cent to 32 per cent. The second generation selfed lines are much more variable in this respect than those of the first generation. In several cases both low- and high-yielding strains were obtained from the same parental selfed line, showing a marked segregation of factors for growth characters. Even in the third generation, where greatest loss in vigor has occurred, a few lines are not significantly different in yield from the original open-pollinated strain.

The relationship for yield of forage was studied between first and second, and second and third generation selfed lines. Each of the 41 second generation lines was correlated with its parental line, and a correlation coefficient of $r=0.14 \pm 0.10$ was obtained. Similarly, each of the 37 third generation

lines was correlated with its parental line, the correlation coefficient in this case being $r = 0.06 \pm 0.11$. In neither instance is there any significant correlation between the yields of successive generations. The absence of any degree of positive relationship may probably be explained in both cases by the relatively small number of parental lines as compared with the number of progeny lines, together with the fact that the progenies of each parental line were so widely differentiated with respect to vigor of growth.

The third generation results from one cutting are, of course, not strictly comparable with those of the first and second generations from three cuttings. They are strictly comparable so far as first cuttings are concerned because their yields are given in percentage of the cross-fertilized strains which were included in the same test. In order to get an idea of the extent to which a first cutting may be regarded as an index of the yielding power of the different lines in future cuttings, a correlation coefficient was computed for the degree of relationship between the first cutting and the average of three cuttings for the 55 first and second generation selfed lines. A calculated value of $r = 0.89 \pm 0.04$ was obtained which indicates that the yields obtained from the first cutting were highly indicative of the productivity of the strains in future cuttings in this experiment.

This raises an interesting point as to the significance of the high degree of consistency in the yield of selfed lines as indicated by the correlation between the first and average of three cuttings. A correlation coefficient was calculated for the corresponding yield from the 48 checks, and a value of $r = 0.68 \pm 0.06$ was obtained. This correlation coefficient was then compared with that obtained for the selfed lines. The chances are 22 to 1 that the difference is significant.

Since each selfed line and check occupied the same soil throughout and since the other features of the environment were uniform for all, it may be concluded that the higher correlation coefficient obtained in the case of the selfed lines is the result of a more uniform response on the part of the plants to environmental factors. This, in turn, may fairly be attributed to the greater homozygosity of the plants within each selfed line as compared with the normal cross-fertilized plants growing in the checks.

It is interesting to observe how much better is an r of .89 as was obtained for the selfed lines than an r of .68 as was obtained for the check. This is best considered in relation to the "standard error of estimate." If it were desired to predict what yield may be expected for an average of three cuttings from an estimate based on the yields of the first cutting, knowing the correlation between them, such an estimate could best be made by means of the regression equation. The standard error of estimate would then give a measure of the statistical reliability of such an estimate. This may be calculated by the use of the formula $S = \sigma \sqrt{1-r^2}$, where S is the standard error of estimate, σ the standard deviation of the yield values for the first cutting, and r the correlation between the first and the average of three cuttings. If the yield values for selfed lines be designated by subscript s and for the checks by subscript c, by substitution for r with above formula we obtain:

$$S_s = \sigma_s \sqrt{1 - (.89)^2} = \sigma_s .4560 \text{ or } 46\% \text{ of } \sigma_s.$$

$$S_c = \sigma_s \sqrt{1-(.68)^2} = \sigma_c .7284 \text{ or } 73\% \text{ of } \sigma_c.$$

In other words the standard deviations of the predicted values are reduced 54 and 27 per cent. respectively from the standard deviations of the original values. From these equations it is possible to say that for estimating purposes an r of .89 reduces the standard deviation twice as much as does an r of .68. This helps to bring out the true significance of the greater magnitude of the correlation coefficient in the case of the selfed lines over that obtained for the checks. Apparently, therefore, the increased homozygosity of the plants in the selfed lines over normally cross-fertilized plants of the standard varieties used as checks has a very pronounced effect making for greater uniformity of physiological behavior under a given environment.

One other point should, perhaps, be considered in connection with the results for total yield of plants. To what extent does the green weight of the different lines vary in moisture content? To answer this question a considerable number of 1,000 gram samples in duplicate were taken at the time of cutting and weighed. They were then dried to a constant moisture content of about 7 per cent in the laboratory. The open-fertilized material was sampled in nearly all cases and in addition those first and second generation row plats which seemed to differ most from the normal with respect to vigor of growth or stage of maturity. Table 3 gives the percentage of dry weight for the determinations which were made.

TABLE 3. *Percentage Dry Weights of Alfalfa Samples.*

Generation	Checks	STRAIN NUMBERS I	II	III	IV	V	VI	VII	VIII	IX	XII	XIII
	Av. of 4											
Cross-fertilized ------	26	28	24	27	25	24	25	26	27	25	26	27
First generation selfed		29	24	28	25	25	25	26	27			
Second generation selfed		26	25	26		25.5	25			26	25	27

Considering the fact that sampling was done purposely from those rows in particular which were most likely to show a difference in moisture content and the further fact that comparisons are of most value in this study between generations within the strain, not between strains, it seems quite evident that little error is introduced by using green weights.

The second cutting was made when the checks were about 50 per cent in bloom. At that time it was evident that the second generation strains were more or less delayed in stage of maturity. This factor, more than any other, would tend to give them a moisture content somewhat greater than normal. A relatively larger moisture content, however, would be equivalent to a lower yield of dry matter, and this would accentuate rather than diminish the already considerable differences between the productivity of second generation as compared with open-fertilized and first generation selfed lines. At the third cutting, differences in maturity were not at all conspicuous.

Effect of Self-Fertilization on the Seed Production of Selfed Lines

A study was made of the relative seed production of first and second generation selfed lines as compared with the seed yield from plants of the same strains grown from cross-fertilized seed. The seed was harvested in 1926 from 10 consecutive normal plants in each row plat. Danger of loss of seed by shattering was obviated by hand picking the pods. After drying

the pods in the laboratory, they were threshed by hand and the weight of the seed obtained in grams. In table 4 the yield of seed for first and second generation selfed lines is expressed in percentage of the yield of seed from the original cross-fertilized plants.

TABLE 4.—*Seed yields of Alfalfa from First and Second Generation Selfed Lines expressed in percentage of the seed yield from plants of the same strain which were grown from cross-fertilized seed.*

Strain No.	Cross-fertilized	First generation selfed	Second generation selfed lines	
			Mean	Range
I	100	28.3	14.5	10.5 – 18.3
II	100	26.1	31.9	14.1 – 52.2
III	100	49.2	20.9	5.3 – 57.8
IV	100	20.0	17.9	0 – 17.9
V	100	79.2	25.1	17.2 – 35.4
VI	100	52.6	12.2	6.9 – 21.4
VIII	100	27.5	19.6	6.6 – 32.6
IX	100	68.1	39.9	17.5 – 71.4
XII	100	38.9	33.4	6.8 – 49.6
XIII	100	233.3	86.0	25.3 –205.3
VII	100	47.9		
X	100	38.3		
XI	100	92.8		
XIV	100	43.1		
Average first 10 strains	100	62.32	30.14	

Probable errors for seed yield have been computed on the basis of the two sets of checks consisting of 24 each. Here also the seed was harvested from 10 consecutive normal plants in each row plat. For the variety Grimm Sask. 666, the probable error was 16.12 per cent. and for the standard Grimm variety 15.24 per cent. A correlation was computed for the seed yields of adjacent check plats and a calculated value of 0.13 ± 0.13 was obtained. It will be remembered that in the case of the green weight of forage the correlation between adjacent plats gave a value of $r = 0.74 \pm 0.09$. A comparison of the two results serves to emphasize the fact that soil variability has relatively little effect on seed production as compared with the effect which it has upon total yield.

An explanation of the somewhat large probable error must be sought in the varied response of the checks themselves to climatic factors, and this in the last analysis is accounted for by differences in the seed setting of the plants within each check row. Ten plants of alfalfa are really too few to give a random sample of a population of plants which are notoriously variable in this character. On the other hand, ten plants each of 117 row plats for a perennial crop like alfalfa, represent a very considerable number of individuals, especially in view of the labor, space, and expense involved. As it happens, the differences involved are obviously highly significant.

The results presented in table 4 show very clearly that the yield of seed is decreased very markedly with each generation of selfing. The reduction in seed setting for the first selfed generation is to the cross-fertilized as 62 to 100, and for the second selfed generation as 30 to 100. Second generation selfed lines of strains No. VII, X, XI, and XIV were not available, the seed having been accidently lost when the material was being taken from a burning building in which it was stored.

The average amount of reduction in seed yield, however, is relatively less interesting than some other features of the data. It is very apparent that the decrease in yield of seed is more or less related to loss of vigor. In general, both seed production and size of plants decrease with successive generations of selfing. A careful inspection of the data also shows that there is some tendency for the higher seed-yielding first generation selfed lines to produce second generation selfed lines, one or more of which are relatively good seed producers. It was thought desirable that these relationships should be studied more precisely. This was done and the results expressed in terms of correlation coefficients.

When seed yield was correlated with the average of three cuttings of forage, a correlation coefficient was obtained of $r = 0.49 \pm 0.07$. The relationship between the two classes of variates will be more evident by reference to the correlation surface presented in table 5.

The correlation coefficient clearly indicates that loss in vigor was accompanied to a considerable extent by decreased seed production. The correlation is probably, but not necessarily, an intimate relationship. This conclusion is further borne out by the fact that no correlation whatever ($r=0.04 \pm 0.10$) was found where a similar relationship was sought between the seed yield and total yield of plants for the 48 check row plats.

TABLE 5.—*Correlation between seed production and yield of forage of first and second generation selfed lines of alfalfa in 1926.*
Percentage seed yields

Percentage yields of forage. Average of 3 cuttings.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	Total
45		1	1	1					1													4
50	2	1																				3
55	1		2																			3
60						1	1							1					1			4
65	2		1			1																4
70				2		1		1														4
75			1		1			1	1	1		1										6
80			1	3	1	1				2						1						9
85					1	1	1						1									4
90			1					1			1		1	1								5
95							2												1			3
100																						
105										1												1
110							1															1
115																						
120																					1	1
	5	2	7	6	3	5	5	3	2	4	1	1	2	2		1			2		1	52

$r = 0.49 \pm 0.07$

The scatter diagram of table 5 also shows that relatively high seed yielders were found both among vigorous and non-vigorous lines. This will be even more evident if it is remembered that a class value of 100 per cent. represents the vigor and seed production of the normal cross-fertilized material. It must also be pointed out that two variants had to be omitted from the table, one being a vigorous first generation selfed line with a seed yield of 233 per cent. and the other a non-vigorous second generation selfed line with a seed yield of 205 per cent. Considering, therefore, the distribution of variants with respect to the two characters of vigor and seed setting, it is evident that, in a number of cases, self-fertilization has resulted in the

segregation of selfed lines for high and low seed production, independent of the degree of vigor which they possessed.

As mentioned above, inspection of the data in table 4 seemed to indicate some degree of correlation for seed setting between first and second generation selfed lines. A numerical value of $r = 0.46 \pm 0.08$ was found for this relationship when the average seed setting of each of the second generation selfed lines was correlated with the corrsponding first generation selfed lines. The correlation surface is shown in table 6.

TABLE 6.—*Correlation for seed production between first and second generation selfed lines of alfalfa in 1926.*

Seed yield classes in grams. First generation selfed lines.

Seed yield classes in grams. Second generation selfed lines	35	50	65	80	95	110	125	140	155	170	185	200	215	Total
5	3		2	2										7
15	1	2								1				4
25	1	1	1	3										6
35	4	1								1				6
45	3	1								2			1	7
55	1			1									1	3
65														
75	1									2			1	4
85														
95				1									1	2
	14	5	3	7						6			4	39

$r = 0.46 \pm 0.08$

The character of seed production in alfalfa is of great economic importance, and this rather marked tendency for it to be transmitted from one selfed generation to the next is quite significant, especially in view of the remarkable variability of normally cross-fertilized alfalfa plants with respect to their seeding habits. It indicates the possibility of breeding for high seed production by the method of selection within self-fertilized lines. The high yield of seed obtained from a few of the second generation selfed lines is a further indication in the same direction. That a fair amount of seed was secured from the majority of the lines suggests that sterility will not be a too serious difficulty in obtaining fertile inbred strains which are homozygous for other important characters.

Self-Fertilization in Relation to Winter-Hardiness

Another character of alfalfa which has primary economic importance is that of winter-hardiness. The capacity of an alfalfa variety to withstand low temperatures is an essential requisite for its successful production throughout northern United States and Canada. This qualification more than any other is responsible for the enormous popularity of the Grimm variety. Special note therefore, was taken of the effect of self-fertilization on the behavior of selfed lines during the winter of 1925-1926.

Temperatures during this winter season were less severe than usual and little or no winter killing was observed under ordinary field conditions within the hardier varieties. The writer has frequently observed, however, that when single alfalfa plants are spaced three or more feet apart in the nursery, they are much more likely to be winterkilled than when grown from seed

in a thickly sown row or plat. Many causes might be suggested for this circumstance but the fact is mentioned here only as one reason for the appreciable number of plants which were lost in a few cases, although the winter was comparatively mild. Table 7 gives the number of alfalfa plants which were killed within the different strains which constitute the material of the present investigation.

TABLE 7.—*Number of alfalfa plants which were killed during the winter of 1925-1926 in cross-fertilized, first generation selfed, and second generation selfed lines of each strain.*

Strain No.	Cross-fertilized	First generation selfed	Number of second generation selfed lines						
			1	2	3	4	5	6	7
I	0	0	0 39*	1	0 26	0 20			
II	2	0	3	0 39	4	1	10 32		
III	5	5	9	5	5	12	5	4	20
IV	11	21	14 30	30 30					
V	0	0	0	1	1	1			
VI	4	1	2 32	0 22	0 28				
VII	7	12							
VIII	0	2	0	1					
IX	1	4	0	3	2 32				
X	1	0							
XI	0	0							
XII	1	1	1	2	1	2 27			
XIII	4	5	8	0	8	1	25	3 31	3 32
XIV	0	0							
Turkestan	21								
Semipalatinsk	2								
Grimm 451	2.46	Average of 24 checks							
Grimm 666	1.46	Average of 24 checks							

*All of the 119 row plats had 40 plants each except 14 in which cases the number of plants are indicated.

The results presented in table 7 are of considerable interest from the viewpoint of the present study. Inheritance has clearly played an important part and segregation into hardy and non-hardy lines is plainly indicated in the second generation of self-fertilization. Strains IV and VII may be cited as obvious cases in which lack of hardiness has been transmitted in some degree from one generation to another. In one second generation line of strain IV, every plant was winter killled. Lines III and XIII are notable illustrations of segregation in the second generation of selfing for hardy and non-hardy families of plants.

In striking contrast to the strains in which inherent non-hardiness made an appearance are such strains as numbers I, V, VI, VIII, IX, X, XI, XII, and XIV, in which practically no winter killing occurred. The wide difference in the results for Turkestan and Semipalatinsk are of interest in this connection, the former normally being considerably less hardy, and the latter

even more hardy than Grimm alfalfa. These varieties were included in the nursery for purposes of comparison.

All of the 119 row plats, on which hardiness data are recorded in table 7, had 40 plants each, except 14 of them, in which cases the exact number is indicated immediately below the number of plants killed. The 48 checks averaged 2 dead plants each. Many of the other row plats also lost 1, 2, or 3 plants. Evidently too much importance should not be attached to these small numbers. Numbers of 5 or more do seem to have significance. The nature of the data, however, does not require fine distinction even if such were possible.

It should also be pointed out that the incidence of winter killing in all of the checks and the row plats which only suffered slightly was quite at random as to location and equally so as to whether the dead plants had been listed the previous fall as relatively weak, medium or strong with respect to vigor of growth. This is obviously an important point since protection, or lack of protection, against low temperatures is frequently a matter of distribution of snow covering. Other factors also may cause killing of plants in patches. In this experiment, row plats which suffered the most were practically always paralleled by strong vigorous rows, since no line was more than one row removed from a check.

Brief comment should be made here regarding the nature of the injury which has thus far been attributed to winter killing. In the spring of 1926 it was found that sweet clover had suffered severely from a pathogen causing root rot and that alfalfa was apparently attacked to a lesser extent by the same organism. The etiology of the pathogen has not yet been definitely established. When this condition was first observed, the roots of the dead alfalfa plants in the breeding nursery were examined and invariably found to be rotted. In no case was it possible to determine whether the rotting was primary or secondary. It was found, however, that the hardiest strains of alfalfa (Grimm Sask. 451 and Grimm Sask. 666) in the standard variety test plats and the hardiest variety of sweet clover (Arctic) were much less injured than others. This fact strongly suggests that, if lack of hardiness was not the sole cause of the winter killing, it may have been a predisposing factor for the disease organism. On the other hand, the clearcut manner in which plants were despatched in the breeding nursery argues for the theory that they might not have been killed had they not been attacked by the root rot, since true winter injury usually results, not only in the killing of some plants, but in injury to others, the effects of which persist throughout the growing season. This was not the case in the present instance.

Whether the results which have been presented, with respect to the effects of self-fertilization in relation to winter killing, should be attributed to differences in winter hardiness or disease resistance, or both, cannot be definitely settled. There is some evidence that both have played a part. In any case, inheritance of the character or characters involved and segregation in the second generation of self-fertilization were very apparent.

Occurrence of Abnormalities

Plants which exhibit various forms of abnormal growth and development have been found to be of frequent occurrence in self-fertilized lines of

a number of crops. Of the abnormalities, chlorophyll deficiencies are by far the most numerous.

Lindstrom (21) lists white, virescent white, and yellow, as the three seedling types which occur most frequently in maize. In a test of 1,872 self-pollinated ears which were grown under greenhouse conditions, Hutchinson (15) reports that 530 gave chlorophyll deficient plants in the seedling stage. Hayes and Brewbaker (9) have recorded the frequency of the appearance of chlorophyll deficiencies in 6 varieties of maize commonly grown in Minnesota. The percentage of first year self-fertilized lines which segregated for chlorophyll deficient seedlings varied from 39.4 in Minnesota No. 13 to 7 in Northwestern Dent. Brewbaker (1) found chlorophyll deficiencies in 23 out of 31 selfed lines of rye. Hayes and Barker (8) report white seedlings in 5 out of 12 first generation selfed lines of timothy.

The abnormalities which have been found in maize have proved to be of special value in the study of plant genetics. One of the most interesting phases of these investigations has been that of chlorophyll inheritance. At least eight different factors for virescent seedlings and eleven for white seedlings are known. These represent only two out of several types of chlorophyll abnormalities which occur. Apparently many different loci are involved and in some instances the interaction of factors is complicated, all of which indicates a genetic condition of extreme complexity.

In the course of the present studies with alfalfa, a record was made of the chlorophyll deficient seedlings and other types of abnormal growth of plants in each generation of self-fertilization. The chlorophyll deficient seedlings which appeared were yellowish in color and usually lethal. Abnormalities, other than these, were green in color, but differed from the normal in habit of growth. Most of these could be classed under the general heading of "constricted growth". A type of the latter which occurred most frequently appeared to be due to a shortening of the internodes resulting in the plants having a bunched appearance. This constricted growth of stem was almost always accompanied by a constricted growth of branches which caused the leaves to cluster closely around the stem. Two other types might be appropriately designated as "crinkle leaf" and "pea leaf." All of the abnormalities in the different lines of strain VI were of the first type except 3 plants which had pealike leaves. No other pea leaf plants occurred and the only other crinkly leaf plants were the 9 abnormalities listed in one line of strain III. Table 8 gives the lineage of each selfed line, the number of normal green (Gr) and yellow lethal (Y.L.) seedlings which were grown, and the number of plants which developed abnormally in the field (Ab) in the first and each of the second and third generation selfed lines.

It will be observed that chlorophyll deficient seedlings were found in only one first generation selfed line out of 14, and 9 second generation selfed lines out of a total of 45. It is significant that all of the deficient seedlings, except 2, occurred in strains I and III. None of the third generation selfed lines contained seedlings which lacked chlorophyll. This is not surprising since only 2 of them were descended from lines which exhibited this character in preceding generations. Among all of the material from cross-fertilized seed, some 2,780 plants in all, only one chlorophyll deficient seedling was observed. This occurred in strain I.

TABLE 8.—*Number of normal green seedlings, chlorophyll deficient seedlings, and plants which developed abnormally in the field, in first, second, and third generation selfed lines of alfalfa*

Strain No.	First selfed generation			Second selfed generation			Third selfed generation		
	Gr*	YL†	Ab‡	Gr	YL	Ab	Gr	YL	Ab
I	42	5	4	39	2	4			
				40	2	4			
				27	1	1			
				20	1	0			
II	82	0	1	42	0	0			
				42	0	0	40	0	0
							40	0	0
				40	0	0			
				40	0	1			
				41	0	0	40	0	0
							10	0	0
III	82	0	1	42	0	9			
				42	2	0	40	0	1
				41	0	3	21	0	0
				42	1	3			
				42	0	5			
				42	1	0			
				41	0	4	40	0	1
							40	0	0
							40	0	0
IV	42	0	0	32	0	1			
				31	0	0			
V	82	0	1	42	0	0	40	0	0
							40	0	0
							40	0	0
				42	0	2			
				40	0	0	40	0	0
							40	0	0
							40	0	0
				42	0	2			
VI	40	0	2	32	0	4			
				30	0	7			
				30	0	3			
VII	42	0	0						
VIII	82	0	0	40	0	1			
				41	0	4	40	0	0
							40	0	0
							40	0	1
							40	0	0
IX	82	0	1	40	0	8			
				40	0	7			
				32	1	6	40	0	6
X	42	0	0	40	0	0			
				40	0	0			
XI	42	0	0	40	0	0			
				40	0	0			
XII	82	0	0	42	0	1	40	0	0
							40	0	0
				37	1	10			
				40	0	0	40	0	0
							40	0	0
							40	0	0
							10	0	0
				27	0	1	40	0	0

Strain No.	First selfed generation			Second selfed generation			Third selfed generation		
	Gr*	YL†	Ab‡	Gr	YL	Ab	Gr	YL	Ab
XIII	82	0	0	42	0	0			
				42	0	2	40	0	0
							40	0	0
				42	0	2	40	0	0
							40	0	0
							40	0	0
				41	0	0	40	0	4
				41	0	0	40	0	2
							40	0	1
				31	0	2	40	0	2
				32	0	3	40	0	1
XIV	41	0	0						

* Normal green plants, including abnormalities.
† Yellow lethal seedlings.
‡ Abnormalities other than yellow lethals.

While the small number of plants grown precludes an attempt at precise Mendelian analysis of the results for chlorophyll development and chlorophyll deficiency, it seems clear that the factorial condition which determines the expression of these characters is somewhat complex. On the basis of independent inheritance at least two and probably more recessive factors in the homozygous condition are required to account for the ratios obtained. The dominant allelomorphs of these recessives would then be regarded as duplicate factors for chlorophyll development.

Another explanation which could account for results equally well would be the occurrence of two recessive factors, one in each chromosome of an allelomorphic pair, both being necessary in the homozygous condition for the production of a chlorophyll deficient seedling. The chance mating of two cross-over gametes, both of which contain the two recessive factors in question, would at once give rise to the character. Such a condition would satisfactorily account for a great diversity of ratios.

Other types of abnormalities occurred more frequently than the chlorophyll deficient seedlings. Six of the 14 first generation selfed lines, 27 of the 45 second generation selfed lines, and 9 of the 37 third generation selfed lines, produced one or more plants which exhibited abnormal development. As with the chlorophyll deficient seedlings, these inherent weaknesses showed up more strongly in some families than in others as a result of self-fertilization. Strains I, III, VI, and IX are notable in this respect. In the cross-fertilized material, 6 abnormalities appeared in strain IX, one in strain XII, and 5 or 6 among the 1,950 plants in the check row plats.

What has already been said in the case of the chlorophyll deficient seedlings by way of explaining the results on a factorial basis, applies equally well in the case of these other abnormalities. Practically all of these plants proved to be sterile. The factors involved are therefore recessives and their interaction to produce the characters concerned is probably quite complicated.

Increase in Uniformity of Selfed Lines

Reference should be made to the very marked increase in uniformity in self-fertilized lines. This was most conspicuous in flower color, habit of growth, and quantity and color of foliage, but it could also be clearly

observed in practically all morphological characters. The nursery as a whole presented a striking demonstration of the fact that, in a crop like alfalfa composed of highly heterozygous plants, inbreeding tends to isolate types which are as different from each other as the most strongly contrasted varieties.

II. SELF-FERTILIZATION STUDIES WITH AWNLESS BROME GRASS.

Awnless brome grass (*Bromus inermis*) is the most important perennial forage grass over a large area of the Northern Great Plains region of America. It is well known that brome consists of a multiplicity of forms including both desirable and undesirable types. Some of these are compact, leafy, and fine stemmed, while others are coarse, sparsely-leaved but unproductive. Characteristically the plants possess rhizomes but there appears to be much variation as to the extent of these underground shoots and their persistence in the soil after plowing when the land is in preparation for the next crop. The progeny of selected plants, grown from cross-fertilized seed, invariably display a diversity of types, indicating the heterozygous nature of the brome grass plants as they occur in the field.

Materials and Methods.

In 1923, a breeding project was started with a view to studying the effects of self-fertilization in brome grass and for the purpose of isolating desirable forage types. It was especially desired to obtain non-creeping or slightly creeping forms and to eliminate the strongly creeping plants. The nursery consisted of 450 plants which were grown from seed of selections made the previous year. In selecting desirable appearing plants to be artificially self-pollinated, an effort was made to choose individuals which were as restricted in their system of rhizomes as possible.

The method used for selfing brome grass plants was to enclose the entire plant in a cotton cage* approximately 5½ feet high and 3½ feet square. Cotton sheeting, of a rather close weave, 54 threads to the inch, was used. The base of the cotton cage was soaked in oil and buried a few inches in the soil and the tops kept tightly tied. It is probable that pollen was not absolutely excluded, but it is believed that the method is highly effective in preventing cross-pollination. The apparent uniformity of the selfed lines strongly supports this conclusion.

Seed Setting Under Controlled Pollination

A record was made of the number of seed produced by self-pollinated plants in the seasons of 1924 and 1926. The method used in securing these data was to select at random 15 well matured heads of each plant when the seed was being harvested. These were carefully preserved in separate envelopes. The seeds in each head and the florets which normally produce seed were counted and an average for the 15 heads obtained. The average number of seed per head from each plant was then expressed as a percentage

*The specifications for these cages were kindly supplied by Dr. G. P. McRostie and Mr. R. I. Hamilton, Forage Crop Division, Dominion Experimental Farm, Ottawa, Canada.

of the average number of potentially fertile florets. The plants studied in this manner are listed in table 9 according to their seed number classes.

TABLE 9.—*Distribution of brome grass plants according to the number of seed obtained by self-pollination*

No. of generation	Percentage classes of seed setting in brome grass											Number of plants self-pollinated
	3	8	13	18	23	28	33	38	43	48	53	
First	2	2	3	2	3	2	2	0	0	2	1	19
Second	1	2	6	14	24	9	16	7	13	1	0	93

INHERITANCE OF SEED SETTING

A study was also made of the relationship for seed setting by controlled pollination between the original plants which were selfed in 1924 and their progeny consisting of 93 plants which were selfed in 1926. For purposes of correlation, the seed yield obtained from the progeny of each plant was averaged. A value of $r = 0.55 \pm 0.11$ was obtained, indicating a rather marked inherited tendency with respect to this character. The correlation surface is shown in table 10.

TABLE 10.—*Correlation for seed setting of brome grass under controlled pollination between plants which were selfed in 1924, and their progeny means, computed from 85 plants which were selfed in 1926. The number of seed obtained is expressed as a percentage of the number of normal florets*

Classes for seed setting, 1924	Classes for seed setting, 1926											
	17	19	21	23	25	27	29	31	33	35	Total
3		1			1						2
8		1			1						2
13	2						1				3
18		1							1		2
23						1	2				3
28					1					1	2
33									2		2
38											
43											
48									1	1	2
53				1							1
	2	3		1	3	1	3		4	2	19

$r = 0.55 \pm 0.11$

CORRELATION BETWEEN YIELD, SPREAD OF RHIZOMES, AND HEIGHT OF PLANT IN SELF-FERTILIZED LINES

Twenty-six self-fertilized lines of brome grass were grown in 1925 and 1926. The plants were started in the greenhouse and transplanted into the field in June, 1925. There were two systematically distributed rows of 34 plants each, making 68 plants of each selfed line. In addition there were 4 rows of plants systematically distributed, as checks. The check row plants were grown from commercial seed and handled in the same way as the other material. All plants were spaced 50 inches apart each way.

In 1926, the self-fertilized lines were studied with respect to three plant characters. These were average yield per plant, average spread of rhizomes, and average height. The yield data were obtained by harvesting the plants

when fully headed in July, 1926. The total green weight for each family was then divided by 68 to obtain the average yield per plant. The average rhizome spread in inches was obtained just twelve months after transplanting. A measuring stick was placed across the base of each plant at its widest part and the actual measurement taken from the outermost series of leafy shoots. This appeared to give a very fair index of the extent of creeping habit since the area occupied by the rhizomes of each plant was usually nearly circular and the outer limits of spreading were clearly demarked by leafy shoots. Similarly, the average plant height was obtained for each selfed line. Table 11 gives the data for the determinations made on each of the characters in question, arranged in order of yield.

It is evident from a perusal of the table that a few of the lines yielded about as much as the checks but most of them yielded less and some of them very much less. The lines obviously varied greatly with respect to productivity. The coefficient of variability for rhizome spread is the same as for that of yield, indicating the same degree of variability for both characters. Moreover it is very evident from a superficial inspection of the data that yield and rhizome spread show a strong positive correlation.

TABLE 11.—*Average yield, average spread of rhizomes, and average height per plant of 26 first generation selfed lines of brome grass arranged in order of yield*

Average yield per plant in pounds	Average spread of rhizomes in inches	Average height of plants in inches
4.23	38.30	51.58
4.05	32.52	44.85
4.00*	33.95*	49.39*
3.97	34.99	48.31
3.88	36.12	50.78
3.80	34.26	49.20
3.79	34.84	49.91
3.72	33.70	53.51
3.65	28.76	48.87
3.57	28.48	43.66
3.41	29.40	44.30
3.28	24.71	48.06
3.22	23.54	46.25
3.08	26.85	45.33
3.06	26.93	47.83
3.04	24.64	47.77
2.68	23.70	47.90
2.67	24.70	43.56
2.46	20.99	44.94
2.42	20.42	48.42
2.39	20.33	40.74
2.11	21.55	46.48
2.11	19.59	37.41
1.92	16.52	47.72
1.75	14.29	46.31
1.54	14.90	31.45
Coefficient of variability 25.30	25.44	9.56

*Average of checks.

With respect to height, it may be said that the selfed lines were much less variable for this character, the coefficient of variability being only 9.56 as compared with 25.30 for yield and 25.44 for spread of rhizomes. As will

be shown, a considerable correlation also exists between height and both of the other two characters, but this is not easily apparent from the figures in the table, probably because of the relatively smaller degree of variability which the selfed lines exhibit for height.

This pronounced tendency for yield to vary so consistently with spread of rhizomes suggested that it would be worth while to investigate the interrelationships of all three factors. This was accordingly done, and the following correlation coefficients obtained:

Simple Correlation Coefficients

(a) Correlation between yield and spread, $r = 0.9617 \pm 0.0099$
(b) Correlation between yield and height, $r = 0.6195 \pm 0.0815$
(c) Correlation between spread and height, $r = 0.6162 \pm 0.0821$

Partial Correlation Coefficients

(a) Correlation between yield and spread holding the height constant, $r = 0.9381 \pm 0.0159$
(b) Correlation between yield and height holding the spread constant, $r = 0.1246 \pm 0.1302$
(c) Correlation between spread and height holding the yield constant, $r = 0.0948 \pm 0.1311$

The results show that yield and rhizome spread are correlated to the very marked extent of $r = 0.9381$ entirely independent of height. They also show that while height varies to a considerable extent and about the same degree with both yield and spread of rhizomes, it is correlated hardly at all with yield when the spread is held constant and hardly at all with spread when the yield is held constant.

It might be expected that rhizome spread and height of plant would both be similarly influenced by variation in vigor as between selfed lines, but while this is probably true to some extent, in general it does not appear to be the case since spread is almost as strongly correlated with yield when height is held constant as when the influence of height is not eliminated. On the other hand, when the spread is held constant, the correlation between height and yield almost disappears. It is quite evident that caution must be exercised in drawing conclusions from the yield results of selfed lines of brome as to the effects of self-fertilization on vigor of growth.

These relationships between yield, spread of rhizomes, and height of plants, appear to indicate that variations of rhizome production in brome grass are strongly inherited and that differences in the yield of selfed lines may be due to differences in the extent to which the rhizomes spread. This seems reasonable when it is remembered that during the first season there is relatively little top growth but considerable production of rhizomes. These root at the nodes and send up shoots, thus augmenting greatly the total absorption area of the roots, and the number of loci from which new shoots develop. This, of course, would only be true as in the present case when each plant has all the space necessary for maximum development.

Differences in height, on the other hand, seem to have been mainly a result of soil heterogeneity. The more fertile locations would produce

plants of a little greater height which in turn would favorably affect the yield. Although the differences in height are not great, the two characters are sufficiently interrelated as to account easily for the correlation found between them. Such advantage of location would also be reflected in a little greater spread of rhizomes and this might easily account for the correlation between height and spread. Even a relatively small increase in spread, however, could increase the yield out of all proportion to the increase in height from the same cause, thus maintaining the strong correlation between yield and spread.

It would appear that the considerable reduction in yield of many of the selfed lines must either be attributed to loss in vigor following self-fertilization or to the inheritance of genetic factors which independently condition the extent of rhizome development. The data presented do not justify the conclusion that self-fertilization in brome grass is not attended by more or less reduction in vigor of the selfed lines, but, for reasons already stated, the alternative interpretation appears to be more in keeping with the relationships which were found. The fact that most of the selfed lines tended to a more restricted rhizome development than that which characterized the checks may be explained as a direct result of the selection which was practiced in choosing the parental plants for self-fertilization.

III. SELF-FERTILIZATION STUDIES WITH RED CLOVER

The rather extensive literature dealing with the question as to whether or not red clover (*Trifolium pratense*) can be made to set seed by artificial self-pollination has been reviewed by Westgate, Coe, and collaborators (28), Malte (22), Kirk (20), and Williams (29). Literature citations by the last named author are so extensive and recent as to make a detailed review of previous studies unnecessary here. His publication is of considerable interest in that there is presented much information relative to the habits of bees in connection with cross-fertilization under field conditions, as well as the results of researches on the self-fertility of red clover.

The conclusions of many investigators who have studied artificial self-fertilization in red clover have been concisely summarized by Williams as follows:

"If the results of the investigations conducted by the various workers cited above are compared, it will be observed, on the one hand, that DeVries, Fruwirth, Witte, and Jorgensen concluded that red clover is completely self-sterile, when artificially self-pollinated, and that Westgate and Coe, Frandsen, Gmelin and Schlecht were of the opinion that it is probably self-sterile or in any event but very slightly self-fertile, while on the other hand, Roemer, Grabner, Fergus, and Kirk claim to have demonstrated conclusively that red clover contains a few plants which are definitely self-fertile, though the degree of fertility was found to vary very much amongst a few fertile plants."

Materials and Methods

Two varieties of red clover were used in the present studies, namely, Altaswede and Minnesota. The former is a mass-selected variety produced at the College of Agriculture, Edmonton, Alberta. Minnesota red clover is a strain grown from Minnesota seed.

The method used for effecting self-pollination was the same as that employed by Fergus and consisted of bagging the clover heads singly, just as the petals were beginning to show and before any of the flowers had opened. One-quarter pound Kraft paper bags were used for this purpose. After 48 to 60 hours the bags were removed, the clover heads rolled between the thumb and fingers, and the bag replaced and left undisturbed until the heads ripened.

Four hundred and thirty heads in all were manipulated, each head representing a separate plant. Two hundred of these were of the Altaswede variety and the balance of Minnesota red clover. At the same time 30 cross-pollinated heads were taken at random from each variety to get an estimate of the seed set under natural conditions of pollination. The bagged heads were harvested at maturity and carefully examined for seed.

Results of Artificial Self-Pollination

The results obtained by self-pollinating red clover are summarized in tables 12 and 13.

Table 12.—*Results obtained by self-pollinating red clover*

	Minnesota red clover	Altaswede red clover	Both varieties Total	Average
Number of heads self-pollinated	230	200	430*	
Number of heads that produced seeds	58	88	146	
Total number of seed produced	430	904	1334	
Average number of seed set per self-pollinated head	1.87	4.52		3.2
Average number of seed set per open-pollinated head	44	44		44
Average number of seed from selfed seed yielding heads	7.4	10.27		8.83
Percentage of the "normal seed set" by artificial self-pollination	4.25	10.27		7.26

*Each head represents a separate plant.

Table 13.—*The distribution of heads (or plants) according to the number of seeds produced by open and by self-pollination*

Variety and method	Seed number classes of red clover																				
	0	3b	8	13	18	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	T'tl
Minnesota																					
Open-poll.	0		2	2	2	1	3	4	2	2	1	3	2	1	0	1	1	0	0	3a	30
Self-poll.	172	33	13	4	1	5	1	0	0	0	1										230
Altaswede																					
Open-poll.	0					2	3	4	6	2	3	4	3	0	1	0	1	1			30
Self-poll.	112	46	15	5	5	7	1	6	1	1	1										200

a. One of these belongs to class 113.
b. The seed number classes are designated by the center value of each class. Thus 3= 1 to 5; 8= 6 to 10; etc.

Of the 430 heads self-pollinated, 146 produced some seed. The majority of these contained only from 1 to 5 seed but as many as 48 seeds were secured in a single head of both varieties. The average number of seed obtained from heads which were self-pollinated was 3.2 which is 7.26 per cent. of the average number obtained from heads of naturally cross-pollinated plants. Bearing in mind the fact that each clover head in this experiment represented

a different plant, it would appear that some plants are much more self-fertile than others. This conclusion is further borne out by the results obtained in later generations by Fergus, who obtained selfed lines which were highly self-fertile.

Self-Fertilization in Relation to Vigor of Growth, Occurrence of Abnormal Seedlings, and Uniformity of Selfed Lines.

In the following spring the self-fertilized seed was planted in the greenhouse. All of the seeds were pricked with a needle to insure germination of hard seed, a practice which was found to be 100 per cent. successful with sweet clover. Table 14 is a numerical tabulation of the greenhouse notes taken from the time of planting the seed until the seedlings were transplanted into the field.

Table 14.—*Summary of observations on greenhouse plantings of red clover seed from self-pollinated plants*

	Altaswede variety	Minnesota variety	Total
(1) Seeds planted*	692	327	1019
(2) Seeds germinated	492	257	749
(3) Chlorophyll deficient seedlings	41	†	
(4) Albina seedlings in (3)	24	†	
(5) Weak seedlings	155	†	
(6) Number of seedlings that died in the greenhouse‡	80	121	201
(7) Number of seedlings transplanted into the field	412	136	548
(8) Number of self-fertilized lines represented in (7)	81	34	115

† Data not taken.
* The maximum number of seed of any one family planted in the greenhouse was 20.
‡ There was no loss from damping-off or mechanical injury.

It will be observed from table 14 that a considerable number of the seeds failed to germinate and of those which did germinate, a large number produced weak seedlings. These never grew very large and some of them died before transplanting time. Small size and lack of vigor characterized many of the families of seedlings which appeared otherwise healthy in form and color. On the other hand, of 73 seedlings which were grown from seed of cross-pollinated plants of the Altaswede variety, only 6 could be classified as weak. The difference in vigor of the plants from cross-fertilized seed as compared with most, but not all, of the plants from self-fertilized seed was very evident even in the greenhouse.

Forty-one out of a total of 492 seedlings of the Altaswede variety were chlorophyll deficient. These were found in 21 out of the 81 self-fertilized lines studied. Twenty-four of the chlorophyll deficient plants were albinos which never developed beyond the seed leaf stage. The others had pronounced etiolated leaves. Chlorophyll deficiency has already been discussed in connection with alfalfa under the heading of abnormalities which commonly occur as a result of self-fertilization.

The seedlings which had been growing singly in 3-inch pots were then transplanted into the field. One hundred and fifteen lines in all were

represented, many of which had only a very few plants. Several lines, however, contained 15 to 20 plants. Conditions for growth were quite uniform and favorable.

In the field the families of red clover from self-fertilized seed made very interesting material for observation in two important respects, namely, their lack of size and vigor as a whole, and the greater uniformity possessed by plants within each family as compared with plants in the checks from cross-fertilized seed. Reduction in size and vigor was an outstanding characteristic. Table 15 classifies the plants as a whole with respect to development.

TABLE 15.—*Comparison of red clover plants from self-fertilized seed with plants from open-fertilized seed of the same varieties with respect to vigor of growth*

Variety and Treatment	Number of plants expressed in per cent.			
	Dead	Weak	Medium	Strong
Altaswede plants from self-fertilized seed..	2.1	35.0	42.0	20.9
Altaswede plants from open-fertilized seed	0.	2.7	11.0	86.3
Minnesota plants from self-fertilized seed	11.6	47.3	32.6	8.5
Minnesota plants from open-fertilized seed	.0	30.0	20.0	50.0

The comparison with plants from seed produced by cross-fertilization is a fair indication of the loss in vigor due to selfing, although it does not give an adequate idea of the great variation between the lines in vigor of growth. Many of them were greatly reduced while others were intermediate and a very few appeared to be quite as vigorous as the checks.

The second obvious difference between the cross-fertilized plants and the self-fertilized lines of red clover was a marked reduction in variability of the latter. All of the plants were studied with respect to a number of the most conspicuous characters. Notes were taken on vigor of growth, habit of growth, number of stalks, leafiness, size of leaves, color of leaves, leaf markings, degree of pubescence, and the presence or absence of flowers. It is difficult to present such data so as to give a picture of the nature of the variability, but it served very well for the purpose of analyzing the different families of plants with respect to the degree of uniformity for the characters in question. A majority of the lines were found to be quite uniform for one or more of the characters studied. A few of the weak lines appeared to possess a remarkable degree of uniformity in nearly every respect. The more vigorous lines, however, showed considerable variability in nearly all characters although more uniform than the cross-fertilized material.

DISCUSSION AND CONCLUSIONS

The results obtained in the investigations with alfalfa, brome grass, and red clover are of greatest interest in relation to the theoretical and practical bearing which they have on the general problem of crop improvement by means of inbreeding and selection within self-fertilized lines. The more extensive is our knowledge of the phenomena which relate to the inbreeding of naturally cross-fertilized plants, the more dependable will be the foundation upon which to construct a sound system of plant breeding that will apply to the numerous crops which have hitherto received comparatively little attention because of their mode of pollination. The methods of experimentation

which have yielded such promising results with maize have now been used to a greater or less extent with a large number of widely different kinds of crops, so that it is possible to generalize with some degree of confidence, as to the genetic and biologic effects of self-fertilization and the inherent possibilities of inbreeding as a means of improving crop plants that are normally cross-fertilized.

Self-fertilization in maize has been shown by many investigators to result in reduction in size and vigor, the isolation of apparently uniform lines which differ in definite morphologic characters, and the occurrence of undesirable characters including abnormalities of various kinds. These phenomena have been adequately explained as being the logical result of increased homozygosity. In general, the same results have been found to occur for all of the normally cross-fertilized crops which have been studied including alfalfa, brome grass and red clover in the present investigations.

With respect to the effect of self-fertilization on size characters, the data clearly demonstrate that selfed lines of alfalfa are markedly reduced in vigor of growth. Inbreeding alfalfa resulted in a progressive decrease in yield with each of the three generations of selfing. A few of the strains, however, were not significantly different in yield from the open-pollinated variety. Alfalfa therefore behaved in this respect somewhat similar to rye and sunflowers in both of which certain selfed lines were found to be as vigorous as the commercial strain. Red clover differed from alfalfa only in that a greater reduction in vigor was to be observed in the first generation of selfing. Brome grass, on the other hand, showed relatively little tendency to reduction in vigor of growth. The results with this crop seem to agree more nearly with those which have been obtained for timothy.

It is rather remarkable that the selfed lines of some crops like maize, red clover, and alfalfa are markedly reduced in yield as a result of self-fertilization while others like those of timothy and brome grass are relatively strong and productive. It is also a curious fact that of the many thousands of selfed lines of maize which have been studied, not one has been shown definitely to be as vigorous as its cross-fertilized progenitor, while in such crops as rye, sunflowers, and timothy, there is good evidence that some selfed lines have been obtained which are at least as vigorous as the best commercial varieties.

The answer to this problem is by no means clear and an adequate explanation must await further investigation. It seems evident, however, that the differential effect of self-fertilization in these crops must be attributed to the genetic constitution of the plants. In seeking for a tentative explanation one naturally thinks in terms of factors which are favorable for growth and of those deleterious recessive factors which affect development adversely.

In maize, it has been found that abnormalities occur with exceptional frequency, that nearly all of them behave as recessives in inheritance, and that they are widely distributed throughout the entire chromosome complex. Many of these deleterious factors must be closely linked with favorable growth factors which also are probably very numerous and located in many different linkage groups. Under such conditions it would be very difficult to obtain a homozygous strain of maize which would contain a sufficient number of favorable growth factors to produce normal development, and at the same time

one which was sufficiently free from deleterious factors to permit of normally vigorous growth.

In contrast to the genetic condition which appears to obtain in maize, another type of plant might depend for much of its vigor of growth upon a comparatively few favorable growth factors. If it is assumed that the more important of these factors are independently inherited or linked only to a small extent and that harmful recessive factors play a comparatively unimportant role, it would be possible on this basis to account for the fact that selfed lines have been obtained in a number of cross-fertilized crops which appear to be perfectly normal in vigor and yielding ability.

It must be remembered, however, that the geneticist has no means of determining whether the number of genetic factors involved for any particular character are numerous or not, except by crosses between lines which differ in the expression of the character. It appears much more probable that the differences in question between crops are referable, not to the absolute number of growth factors which may be exceedingly numerous, but rather to whether the necessary growth factors are heterozygous to a much greater extent in some crop plants than in others.

In regard to the uniformity of the selfed lines of alfalfa, brome grass, and red clover, it is only necessary to point out again that reduction in variability with respect to morphologic characters was in all cases a conspicuous result of self-fertilization. Second and third generation selfed lines of alfalfa gave a striking demonstration of the fact that inbreeding tends to isolate types which are as distinct from each other as the most strongly contrasted varieties. It has been demonstrated also that plants within selfed lines may possess a greater degree of uniformity for certain characters which appear to be associated more particularly with their physiologic response to environmental conditions. This has been shown for selfed lines of alfalfa in respect to yielding ability and winter hardiness. If fertile, high-yielding, and hardy strains can be isolated which are homozygous for the factors upon which the more important characters depend, it is logical to assume that valuable improvements may be effected in these crops. Provision will also have been made for suitable pure breeding material with which to study the mode of inheritance of many important plant characters.

It is apparent that self-fertilization of alfalfa, brome grass and red clover results in the same kind of biologic phenomena which has been found to occur in the case of other cross-fertilized plants that have been studied, and that these phenomena may be adequately explained on a Mendelian basis as being the logical result of an increase in homozygosity.

Selection within self-fertilized lines appears to provide a promising mode of attack for the breeding of improved varieties of alfalfa. While most of the selfed lines are considerably reduced in vigor as a result of three generations of self-fertilization, some lines appear to have retained most, if not all, of the original yielding ability of their respective open-pollinated strains. Two generations of self-fertilization have also greatly reduced the yield of seed. Nevertheless, selfed lines were found in some of the strains which are good seed producers. It would appear, therefore, that it may not be a difficult matter to secure selfed lines of alfalfa which are vigorous and also some which will yield at least a normal crop of seed.

Danger of winter killing and the precarious seeding habits of the hardiest available varieties are perhaps the greatest drawbacks to the production of alfalfa over large non-irrigated areas of northern United States and of Canada. Much effort has been expended in trying to improve the crop in these two respects by continuous selection and the introduction of new varieties. Neither method has been conspicuously successful considering the time and expense involved. Inbreeding appears to provide a more hopeful line of approach to improvement in these characters. The results which have been presented show that ability to set seed is inherited to a considerable extent and that segregation has occurred for high and low seed production and for hardiness and the lack of hardiness. Strain number XII is the best example of a wide difference in the amount of seed produced by selfed lines of a single strain. Several second generation selfed lines suffered a rather high mortality of plants during the winter while others of the same strain were practically uninjured.

The experiments with brome grass have demonstrated the possibility of securing satisfactory quantities of self-fertilized seed for purposes of breeding by the method of selection within self-fertilized lines. The characters of high and low fertility are apparently inherited. Selfed lines were obtained which are more uniform than the commercial variety in practically all morphologic characters. This was very marked with respect to creeping habit of growth. Segregation for this character was very apparent, some lines producing a much more restricted spread of rhizomes than others.

In regard to vigor of growth, it may be said that all of the selfed lines, with the possible exception of one or two, appeared to be perfectly healthy and vigorous, but most of them yielded less than plants from cross-fertilized seed. This reduction in yield was shown to be in almost direct proportion to the extent of rhizome spread, which suggested the explanation that inheritance of the latter character may have been the controlling factor in determining yield.

The practical bearing of this discussion has to do with the possibility of being able to secure non-creeping or slightly creeping inbred lines of brome grass which are also vigorous and productive. It seems evident that the facts at our disposal do not preclude such a possibility. In agricultural practice, it is quite probable that several plants with restricted creeping habit of growth may be substituted for a single widely creeping form without prejudice to high yield and with very great profit in respect to ease in eradication. Further investigation will be necessary before this question can be definitely decided.

The effects of self-fertility in red clover have already been considered and found to be not essentially different from those which result from inbreeding in maize or alfalfa. Unlike these crops, however, red clover possesses a high degree of self-sterility, making it difficult to obtain sufficient self-fertilized seed for the needs of a practical breeding program. The results reported by Fergus and those obtained by the writer show that a small proportion of red clover plants are fairly self-fertile when artificially self-pollinated. Williams secured comparatively few seed under his conditions and concluded that "owing to the very small amount of seed produced, it is exceedingly doubtful

if self-pollination can be regarded as a practical stepping stone to the breeding of red clover."

There are several reasons why Williams' conclusions seem to be unduly pessimistic. Out of 430 plants self-pollinated in the experiments herein reported, 24 produced over 20 seeds each and 67 gave more than 5 seeds each. These were the produce of only one head per plant. If the problem of discovering self-fertile lines were attacked in a wholesale manner and a real attempt made to improve the technique, the result might go far beyond present expectations. Considering the importance of the crop, the effort should be well worth while.

There is reason to believe also that once selfed lines are obtained from the more highly self-fertile red clover plants, the degree of self-fertility may be expected to increase with successive generations of selfing. It has been necessary to discontinue selfing work with red clover at the University of Saskatchewan owing to the severity of frost injury, but certain of the original selfed lines were grown at University Farm by Dr. H. K. Hayes and these have now been selfed for four successive generations. In 1926, every plant produced some seed, the number of seeds ranging from 2 or 3 to 40 or 50 per plant. It cannot be said that they are more self-fertile than the original propagants, but on the average they certainly possess a greater degree of self-fertility than did the original heterogenous population of plants from which they came. It is interesting to note also that some of these fourth generation selfed lines appear to be as vigorous as plants from normally cross-fertilized seed of the same variety.

The conclusion seems justified that some red clover plants are more self-fertile than others and that self-fertility in red clover is to some extent an inherited character. Fergus contended that such was the case and Williams thought that his results pointed in the same direction. If this is true, the task of obtaining numerous lines which are relatively self-fertile should be well within the range of possibility.

The studies of Westgate and Coe and their co-workers (28) on the prevalence of infertile ovules in red clover are of interest in this connection. The largest percentage of infertility was found to occur in the first crop, and the infertility appeared to be favored by excess of moisture in the soil and atmosphere. During conditions which are favorable for seed setting, the number of infertile ovules ranged from a low percentage or none in some plants to a high percentage in others. They add that "It is very probable that this infertility of ovules is to a greater or less degree a hereditary character and that the production of a high-yielding strain will consist, among other features, in selecting those plants with the least tendency towards infertility."

A condition which is somewhat analagous, though it may not be comparable, occurs in the potato. The great majority of potato varieties produce pollen, nearly all of which is impotent due to dominant factors for sterility. Lack of suitable pollen-producing parent plants, until recently, constituted a serious barrier to potato breeding. It is now known, however, that selfed lines may be rather quickly obtained which will produce an abundance of fertile pollen, owing to the fact that only functional pollen is effective in fertilization, the factors for sterility contained in the sterile pollen being

automatically eliminated. Selfed lines, therefore, become homozygous for the factors which give rise to fertile pollen.

It may be that a genetic condition exists in red clover analagous to that which governs pollen sterility in the potato, in which case the problem of self-fertility in red clover would be greatly simplified. If fertility of ovules is an inherited character, self-fertilization should tend to eliminate the factors which condition its expression. Until the genetics of ovule infertility in red clover has been studied, however, speculation only is permissible as to the possible effect that it may have on increased fertility in selfed lines.

The experimental evidence which has been presented as to the general results of self-fertilization in relation to the improvement of alfalfa, brome grass and red clover, and the results which have been obtained from inbreeding experiments with other cross-fertilized crops, all seem to support the conclusion that self-fertilization and selection within self-fertilized lines provides the logical basis for a sound system of plant breeding for the amelioration of those crops which are mainly cross-fertilized. That this conclusion is justified from a practical standpoint is indicated by the fact that success has been uniformly attained in the isolation of selfed lines, in widely different kinds of crops, which are relatively homozygous for important economic characters. That some of the selfed lines in several of these crops appear to possess normal yielding ability is especially encouraging. The conclusion is justified also on the basis of theoretical considerations as it is generally recognized that the method of controlled pollination as a means of isolation of material of known hereditary constitution appears sound on the basis of the best genetic evidence available.

After self-fertilized lines which possess superior hereditary qualities have been once obtained, the question of how they may best be utilized will probably have to be decided separately for each crop. When it is possible to isolate superior inbred strains which are vigorous enough to replace the heterogeneous varieties now grown, the breeding problem becomes relatively simple. If the inbred lines, however, are characterized by lack of vigor, it will be necessary to recombine two or more of them into a new synthetic variety. Although much remains to be learned regarding the ultimate value of synthetic varieties, there is every reason to believe, and the preliminary results with maize indicate, that such a method of procedure will meet with unqualified success.

SUMMARY

1. Alfalfa was artificially self-pollinated for three generations and first, second, and third generation selfed lines were grown under comparable conditions for comparison with each other and with the open-pollinated parental material. On the average, a pronounced and progressive reduction in vigor of growth was observed for each generation of selfing. A few of the second and third generation selfed lines were not significantly different in yield from the corresponding open-pollinated strains from which they were obtained.

2. The mean yield of seed for second generation selfed lines of alfalfa showed a marked decrease as compared with the seed yield of the correspond-

ing open-pollinated strains. A few second generation selfed lines compared favorably with the original material in the amount of seed produced.

3. A significant correlation coefficient of $r = 0.46 \pm 0.08$ was obtained for the relationship of seed setting between first and second generation selfed lines of alfalfa. This would seem to indicate that the characters of high and low seed production are inherited to a considerable extent.

4. Several second generation selfed lines of alfalfa suffered a rather high mortality of plants on account of injury received during the winter while other lines of the same strain survived in a healthy condition. Self-fertilization apparently resulted in the segregation of genetic factors which condition the expression of the characters of resistance and susceptibility to winter killing.

5. Chlorophyll deficient seedlings and other types of abnormalities occurred in inbred lines of alfalfa as a result of self-fertilization. Lack of chlorophyll appears to be due to the interaction of two or more complementary recessive factors. The allelomorphs of these factors may be regarded as duplicate factors for chlorophyll development.

6. Reduction in variability with respect to important morphologic and physiologic characters in selfed lines of alfalfa was a conspicuous result of self-fertilization.

7. Controlled pollination resulted in the isolation of selfed lines of brome grass which are more uniform than the commercial variety. Segregation with respect to extent of creeping habit of growth was very apparent, some lines producing a much narrower spread of rhizomes than others.

8. The characters of high and low self-fertility in brome grass are apparently inherited. A correlation coefficient of $r = 0.55 \pm 0.11$ was obtained for the relationship of per cent. of possible seed setting between selected plants and their progeny under controlled pollination.

9. The yield of selfed lines of brome grass was shown to be in almost direct proportion to the extent of spread of rhizomes. Most of the selfed lines were less widely creeping than the average for plants of the commercial variety and their yield was reduced accordingly in comparison with the latter. It would appear that spread of rhizomes is strongly inherited and that the expression of this character exerts a dominating influence on yield when each plant has unrestricted space for development. For this reason it is believed that much of the reduction in yield of selfed lines should be interpreted as a result of conscious selection of plant propagants rather than as a direct result of loss in vigor due to self-fertilization.

10. Red clover seed was obtained by artificial self-pollination from 146 out of a total of 430 heads on as many plants. The number of seed obtained from each seed-yielding head varied from 1 to 48, the average being 8.83 seeds. The average number of seed produced for all the self-pollinated heads was 7.26 per cent. of the average number obtained from open-pollinated heads.

11. Chlorophyll deficient seedlings were found in 21 out of 81 self-fertilized lines of red clover.

12. All but a very few of the self-fertilized lines of red clover were markedly reduced in vigor. Most of the lines were considerably less variable than plants grown from cross-fertilized seed.

13. Certain of the selfed lines of red clover, which have been continuously self-pollinated for four generations at University Farm, appear to be more self-fertile on the average than a random sample of plants of the same variety. Some of them also are apparently as vigorous as plants from normally cross-fertilized seed.

14. The results indicate that some red clover plants are more self-fertile than others and that self-fertility in red clover is an inherited character.

15. The results obtained in these self-fertilization studies with alfalfa, brome grass, and red clover, in common with those obtained by investigators who have worked with other cross-fertilized crops, strongly support the conclusion that controlled pollination with selection in self-fertilized lines provides a logical mode of attack in the systematic breeding of those crops which are normally cross-pollinated.

UNIVERSITY OF SASKATCHEWAN,
SASKATOON, SASK.

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PLATE I

A. Alfalfa strain No. 22. Cross-fertilized (row 25) and first generation selfed line (row 26) showing the somewhat less vigorous growth of the latter.

B. Alfalfa strain No. 22. Three second generation selfed lines (rows 29, 30, 31) showing the marked reduction in vigor of growth.

C. Third generation selfed lines of alfalfa.

NOTE: The rows in A and B were photographed at the same distance.

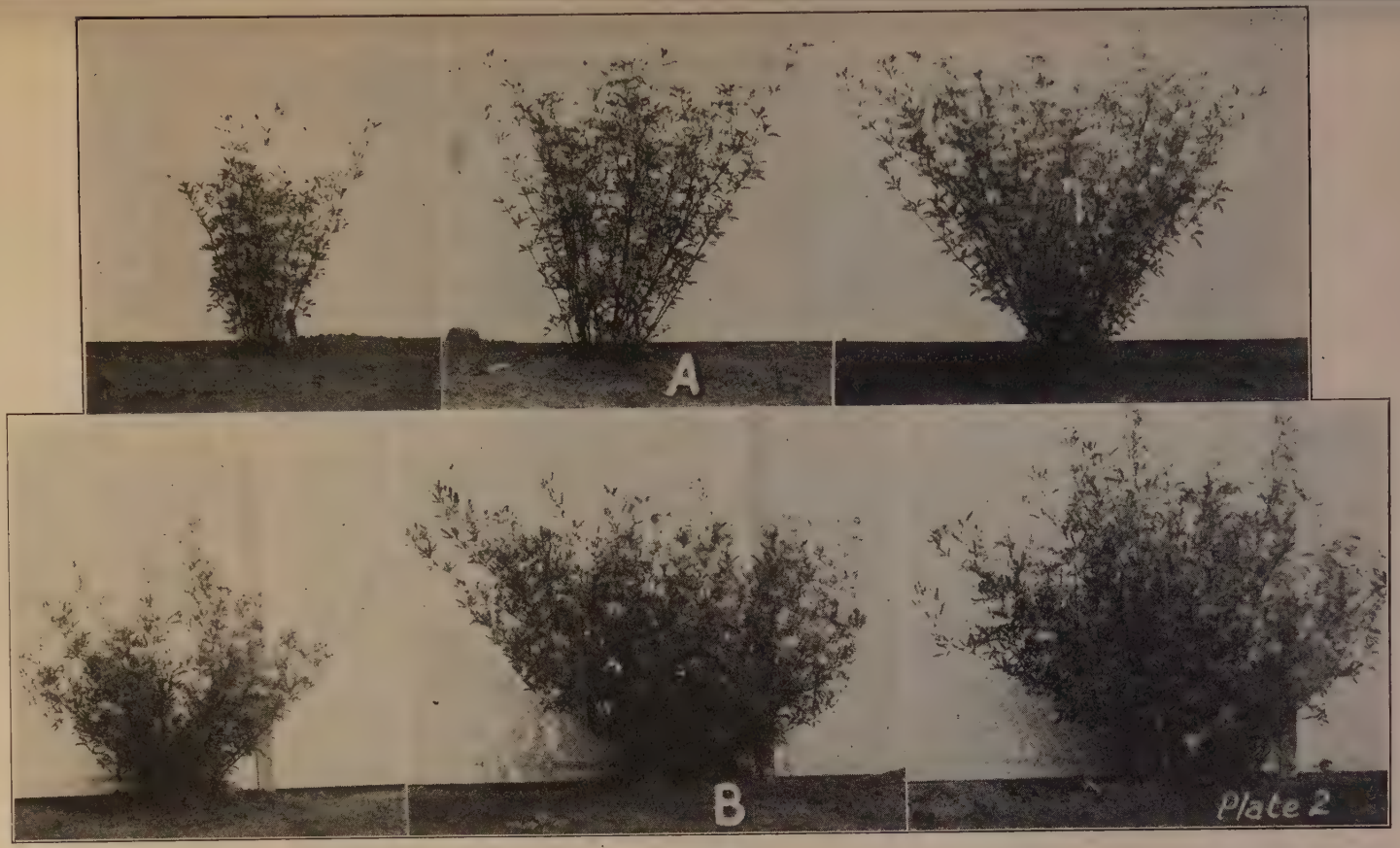


PLATE II

A. Representative alfalfa plants from strain No. 1 showing reduction in vigor due to self-fertilization. Right to left: Open-fertilized, first generation selfed, and second generation selfed.

B. Representative alfalfa plants from strain No. III showing reduction in vigor due to self-fertilization. Right to left: Open-fertilized, first generation selfed, and second generation selfed.

PLATE III

A. A view of the brome grass nursery which shows the method used for enclosing individual plants to protect them from cross-pollination.

B. A view of a part of the brome grass nursery. The centre row is a selfed line, the plants of which have widely spreading rhizomes. This should be compared with the selfed lines shown in Plate IV.

PLATE IV

A. A view of a part of the brome grass nursery. The centre row is a selfed line, the plants of which have rhizomes with considerably restricted spreading habit.

B. A view of a part of the brome grass nursery. The centre row is a selfed line, the plants of which are practically non-creeping.

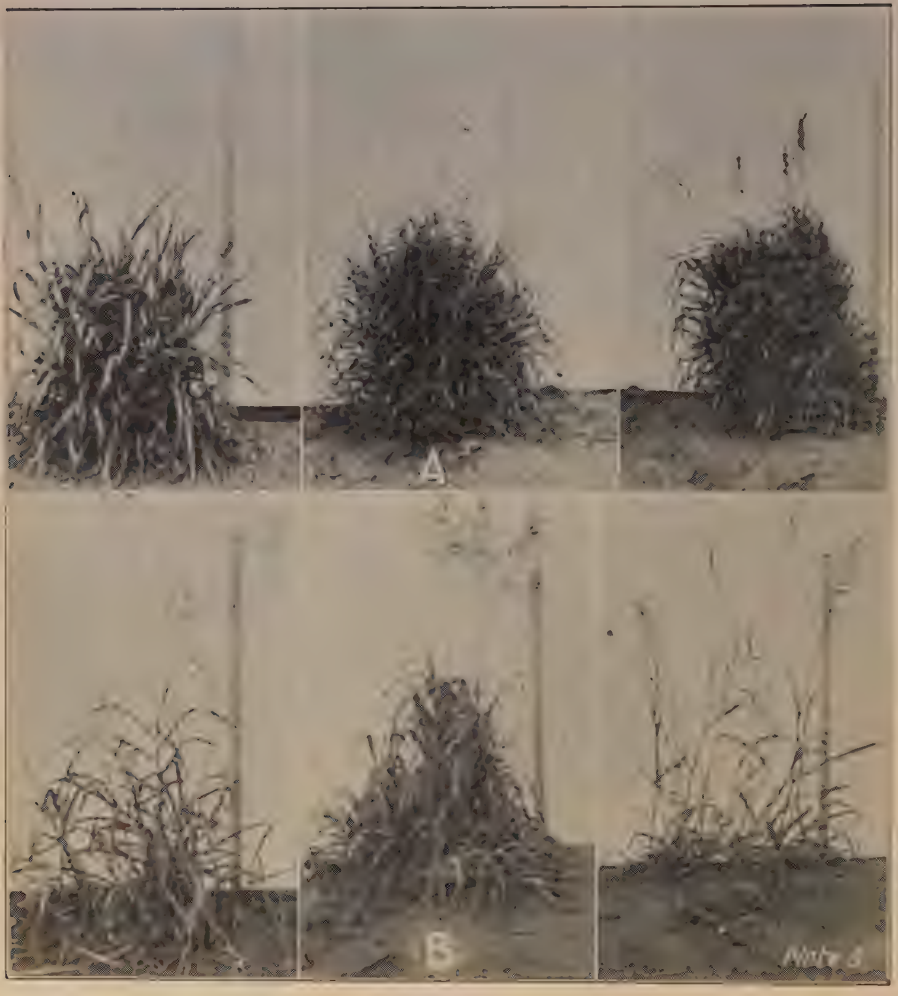


PLATE V

A. Brome grass plants of desirable types from three different selfed lines.

B. Brome grass plants of undesirable types from three different selfed lines

THE INFLUENCE OF AMMONIUM SULPHATE AS A DIRECT SOURCE OF NITROGEN FOR APPLE TREES.*

M. B. Davis†

[Received for publication May 15, 1927.]

During the past decade the increased use of nitrogenous fertilizers for orchard purposes has aroused much interest in the various forms of fertilizers now offered to the public.

Nitrate of Soda has, until recently, been the main source of nitrogen for our fruit crops, but with the increased manufacture of Ammonium Sulphate from our coke ovens with reduced cost of manufacture, this material is now being offered in larger quantities than ever before, and as a consequence information is being sought as to its actual value as compared with Sodium Nitrate.

The importance of a nitrogenous fertilizer having its nitrogen in the immediately available form of nitrate has long been stressed. Such statements as—"but this result can usually be best and most quickly attained by the additions of nitrates." Palladin (1) p. 65 are frequently found in the literature. Russell (2) p. 57, says, "Of all the nitrogen compounds yet investigated nitrates are the best, and in natural conditions, probably the only nitrogenous food for non-leguminous plants."

Palladin (1) pp. 70 and 71, gives briefly the results of Wagner's work which showed that nitrates and ammonium salts have different effects according to the nature of the soil employed. In effect Wagner showed ammonium salts have but little value as fertilizers for soil poor in lime, but that soils rich in that element show almost as good yields with ammonium salts as with nitrates.

The possibility of the direct assimilation of ammonium salts by plants is not new, and has been considered at least as early as 1893, by Pitsch, and by Breal (see Palladin (1) pp. 72). More recently Hutchinson & Miller(3) have presented results to show that wheat plants could utilize ammonia directly but preferred nitrates, but that peas did not exhibit any preference.

Jones and Shive (4) who have done considerable work with ammonium sulphate in nutrient solutions, have shown that where ammonium sulphate was used as a source for part of the nitrogen the ammonium sulphate solutions became more acid in reaction.

Schrader and Auchter (5), working with bearing apple trees in poor vegetative condition concluded that such trees will respond to the application of either nitrate of soda or ammonium sulphate, but that a decided difference in favour of nitrate of soda may be expected for at least the first season.

The authors state that "it is rather difficult to explain why the total and soluble nitrogen of the spurs of the spring sulphated trees at blossoming

*Thanks are due to Mr. H. Hill, Horticultural Division, Ottawa, for assistance in collection of data, and to Mr. R. H. Wilson, Experimental Station, Morden, Manitoba, and Mr. John Walker, Experimental Station, Indian Head, Sask., for assistance in mathematical computations.

†Research Laboratory, Horticultural Division, Central Experimental Farm, Ottawa, in co-operation with the Division of Chemistry and the Division of Bacteriology.

time is lower than that of the check trees in sod." They submit, however, as a possible explanation the suggestion of Truog et al. viz., "High amounts of potash salts or ammonium sulphate on acid soils liberate so much soluble acidity that nitrification and other bacterial activity is hindered." The authors further state "The increased spur growth where ammonium sulphate was used suggest, however, that a portion of the ammonium sulphate became available shortly after the "pink" stage, although not early enough to influence growth as markedly as an application of sodium nitrate."

Russell et al. (6) point out the effect of both temperature and moisture on nitrate production, and draw attention to the significant difference in the quantity of nitrates produced in two soils under the same conditions of temperature and moisture.

Although their work was with wheat their findings have equal significance for the orchardist and may account for the conflicting reports as to the merits of different forms of nitrogenous fertilizer.

Gowda (7) demonstrated the value of limestone in aiding the oxidation of ammonium sulphate under laboratory conditions.

The same author (8) showed that acid phosphate increased the nitrifying power of the soil more than rock phosphate, and that for the particular soil in question there existed an optimum water content for nitrification.

Albrecht and Uhland (9), concluded that a straw mulch, by cutting down evaporation, lowering the soil temperature and preventing aeration, induced an unfavorable environment for nitrate accumulation.

Shutt and Emslie (10) present results showing that if the value of the influence of nitrogen as nitrate of soda is taken as 100 the value of nitrogen in the form of sulphate of ammonia has a value of only 84. These values were deduced from results with field crops on eight stations.

From the foregoing it would appear that for maximum results ammonium sulphate must undergo oxidation to nitrates, that the rate of this oxidation will depend upon soil temperature, soil moisture, aeration, calcium content, and soil acidity and soil type.

This would indicate that the value of ammonium sulphate for orchard purposes would depend upon the type of soil and soil conditions of the orchard in question. The ultimate weight to be placed upon these two sets of limiting factors would in turn be influenced by what is found out in the near future concerning the optimum period for nitrogen application to orchard soils and the ability of apple trees to utilize ammonia as a direct source for nitrogen.

The Experiment

In order to obtain some information on the ability of apple trees to utilize ammonium sulphate as a direct source for nitrogen a pot experiment with apple trees was organized at the Horticultural Division, Central Experimental Farm, Ottawa, in 1925.

Thirty-eight trees were used for this purpose, all two years old, of the variety Melba, and all selected for uniformity of size and condition as far as possible. These thirty-eight trees were divided into three groups of ten and one of eight, the three groups of ten being placed in the following series, Sulphate of Ammonia, Nitrate of Soda, No Nitrogen; and the group of eight constituting a total check.

All trees were sterilized in corrosive sublimate 1-500 for 2 hours, this strength and period having been previously determined as being sufficient to kill the nitrifying organisms attached to the tree roots.

The Substratum

Pure sandstone, ground especially for the occasion, was used as a substratum. This sand analysed as follows:—

Moisture	.02
Loss on ignition	.30
Mineral matter insoluble in acid	98.84
Oxide of iron and alumina	.45
Lime (CaO)	.10
Magnesia (MgO)	.04
Potash (K_2O)	.07
Phosphoric acid (P_2O_5)	.05
Undetermined	.13
	100.00

This analysis was supplied by the Division of Chemistry, Central Experimental Farm, Ottawa.

All pots and sand were sterilized in a high pressure sterilizer for a period of five hours, and all utensils including work table, were thoroughly scrubbed with a strong solution of corrosive sublimate. The trees were watered with water determined as being free of nitrifying organisms, and the tops of all pots were covered with sterilized cotton wool to guard against inoculation with nitrifying organisms.

The Nutrient Solutions

The pots were placed in a greenhouse on March the 16th, and the following solutions were applied to the different series.

Nitrate Series

A		B	
$MgSO_4$	2 grams	$CaCl_2$	3 grams
KH_2PO_4	2 grams	$CaSO_4$	2 grams
$NaNo_3$	7.5 grams	H_2O	95 c.c.
Kcl	1 gram		
H_2O	87.5 c.c.		

Both A and B were diluted 1 to 6, mixed together and applied in the proportion of 1/9 of the dilute solution to each pot.

Ammonium Sulphate Series

Exactly the same as above except that 5.1 grams $(NH_4)_2SO_4$ were substituted for 7.5 grams $NaNo_3$ in Solution A, and in Solution B, 4 grams $CaCl_2$ instead of 3 grams.

No Nitrogen Series

Formula the same as for the Ammonium Sulphate Series except that $(NH_4)_2\ SO_4$ was withdrawn.

Check Series

This series received only water. No nutrients whatever were applied.

QUANTITIES APPLIED

The first application was made on March 26, followed by one on April the 7th, and April the 23rd, all at the same rate, making a total application of ⅓ the formula strength per pot. In addition a fourth application at twice the former rate was made on May the 18th.

This gave the two nitrogen series the following total amounts of each element per pot:

	Nitrate of Soda Series	Ammonium Sulphate Series
Sulphur	.544 grams	1.286 grams
Magnesium	.223 "	.223 "
Potassium	.605 "	.605 "
Phosphorous	.251 "	.251 "
Calcium	.925 "	2.203 "
Sodium	1.111 "	—
Nitrogen	.682 "	.594 "
Chlorine	1.311 "	1.660 "
Totals	5.652 "	6.822 "

The amounts of each element for the No Nitrogen and check series would be the same as for the Ammonium Sulphate Series less the nitrogen and minus .732 grams of sulphur.

THE HYDROGEN ION VALUE OF THE SOLUTIONS

The pH. value of each of the solutions before application as determined by the Chemistry Division with the Potentiometer was:—

Nitrate of Soda Solution	6.23
Ammonium Sulphate Solution	6.46
No Nitrogen Solution	6.23

The effect of the sand on the pH. value may be judged by the following, which shows the pH. value of the sand itself and the pH. value of the solution after having been passed through the sand:

pH value of the sand	= 7.14
pH. value of the $NaNo_3$ solution after being passed through the sand	= 6.96

In addition the following values of the sand were determined in late summer by the Potentiometer and supplied by the Chemistry Division, Experimental Farm, Ottawa:

Check Series	7.75
Nitrate Series	7.55
Sulphate Series	7.55
No Nitrogen Series	7.60

While it is regrettable that the pH. values of the sand were not collected at different periods yet it is evident from the above that neither of the nitrogenous solutions very greatly disturbed the pH. value of the sand over the check for any extended period.

Tests for Nitrifying Bacteria

Tests of the Ammonium Sulphate Series for the presence of nitrifying bacteria were conducted by the Dominion Bacteriologist, (Dr. A. G. Lochhead) and staff. The following table as supplied by Dr. Lochhead shows fairly conclusively that the pots were kept practically sterile until after April 20th, and that even as late as June 10th, only traces and very small amounts of nitrites were found.

APPLE TREE NUTRITION EXPERIMENT (HORTICULTURAL DIVISION)

Tests for nitrifying Bacteria in Sample of Sand Taken from Pots of Ammonium Sulphate Series.

	Date of Test	Pot Number 1	2	3	4	5	6*	7*	8	9	10	Check uninoc.	Check Garden soil	Check Tap water
1	Mar. 20–25	—	—	—	—	—	—	—	—	—	—	—	++++	—
2	Apr. 3–25	—	—	—	—	—	—	—	—	—	—	—	++++	—
3	Apr. 15–25	—	—	—	—	—	—	—	—	—	—	—	++++	—
4	Apr. 20–25	—	—	—	tr.	—	+	+	—	—	—	—	++++	—
5	June 10–25	—	—	—	tr.	tr.	+	tr.	tr.	+	—	—	++++	—

Tests were made for the presence of nitrites in a nutrient solution containing ammonium sulphate as only source of nitrogen, which were inoculated with sand from different pots, and incubated for two weeks.

Test used—alpha-naphthyl-amine and sulphanilic acid.

On June 10th, tests were also made on additional pots as follows, all giving negative tests for nitrites:

1. Check pot without nutrient solution.
2. Check pot containing solution without nitrogen.
3. Check pot containing nitrites.

* Inoculated with nitrifying organisms April 17-25.

Results

Notes were taken from time to time on the condition of the trees and measurements of total growth were recorded on the dates referred to in the following tabulations.

The Ammonium Sulphate Series were somewhat slower in breaking than any of the other series. No difference could be noted in the other three. As will be observed from the presentation of the growth data none of the series showed any increased growth over the Check until after May 14th, when the Nitrate of Soda Series, and the No Nitrogen Series did shoot ahead. It is also noticeable that the Nitrate of Soda Series did not exhibit any marked improvement over the No Nitrogen Series until May 25th, when it began to show pronounced effects from the nitrate treatment. The qualitative notes bear out the deductions from the quantitative data, and it was remarkable to note how the Check and No Nitrogen Series grew and looked on their stored food supply during the first two months of the season. Throughout the early part of the season the Sulphate Series appeared to be somewhat retarded and certainly did not exhibit any superiority over the Check or No Nitrogen Series until the latter part of June and even then only a slight superiority over the No Nitrogen Series. The foliage of this series began to take on the typical look characteristic of insufficient nitrogen, at precisely the same time as the Check and No Nitrogen Series and at this time the Nitrate Series began to assume the richer green which characterizes a sufficient supply of that element.

Results 1925

Following is a summary of the average total growth measurements durin the season of 1925, for the various individuals of each series:

Average Total Growth in inches at different dates.
Ammonium Sulphate Series.

Tree No.	Apr. 24	May 4	May 14	May 20	June 2	June 29	Aug. 8	Nov. 10
1	2.125	4.75	6.75	8.87	19.00	50.50	50.50	50.37
2	.500	1.75	8.00	14.87	40.50	68.50	68.50	68.75
3	1,250	7.50	8.25	19.87	40.50	63.00	63.00	63.25
4	.375	3.75	9.12	30.32	55.25	63.12	63.12	64.25
5	5.125	6.50	7.00	6.62	7.12	8.12	8.12	9.00
6	.500	1.50	3.25	7.87	27.00	41.00	41.00	41.06
7	1.500	4.75	7.00	8.25	17.12	46.00	46.62	47.75
8	2.250	6.00	6.80	9.25	12.50	28.00	28.00	28.75
9	—	—	—	—	10.75	61.25	61.87	62.00
10	5.375	18.00	23.00	64.25	76.12	73.75	76.25	78.00
	19.000	54.50	79.17	170.17	305.86	503.24	506.98	513.12
Mean	1.9	5.45	7.91	17.01	30.58	50.32	50.69	51.31

Mean total growth = 51.31 ± 4
σ = 19.6
C = 38.1

No Nitrogen Series

Tree No.	Apr. 24	May 4	May 14	May 20	June 2	June 29	Aug. 8	Nov. 10
11	.50	1.00	2.37	3.50	22.87	57.75	58.50	58.50
12	2.00	4.75	18.00	27.00	47.00	52.00	52.62	52.62
13	10.50	15.25	18.61	20.75	39.62	47.25	51.25	57.87
14	2.12	5.00	8.87	15.00	18.25	32.50	32.50	32.75
15	.50	1.25	2.12	3.00	3.00	3.00	6.12	8.37
16	6.50	29.50	64.24	76.25	77.25	92.75	92.75	99.12
17	8.75	20.25	37.86	46.87	55.62	58.50	59.00	59.25
18	3.25	14.25	39.36	49.50	52.00	57.75	58.75	60.25
19	3.00	4.75	8.00	12.00	21.50	39.00	42.00	42.50
20	11.00	31.25	36.61	37.00	39.50	41.00	41.00	41.31
	48.12	127.25	236.04	290.87	376.61	481.50	494.49	512.54
Mean	4.81	12.72	23.60	29.08	37.66	48.15	49.44	51.25

Mean total growth = 51.25 ± 4.47
σ = 22.1
C = 43.1

Nitrate of Soda Series
Average total growth at different periods.

Tree No.	Apr. 24	May 4	May 14	May 20	June 2	June 29	Aug. 8	Nov. 10
30	3.50	9.	18.75	25.25	32.75	37.50	37.50	37.75
29	12.75	35.	61.99	76.00	94.50	100.37	101.75	102.37
28	1.37	9.25	26.25	47.25	60.00	87.75	89.37	89.37
27	3.00	6.00	20.25	41.50	68.75	97.50	97.50	99.12
38	8.75	22.50	49.87	64.50	83.62	91.75	96.25	112.62
25	4.50	8.25	14.50	16.50	23.25	64.25	63.00	63.62
24	—	—	—	—	—	5.25	6.25	10.12
23	1.00	1.75	2.37	4.50	25.25	72.00	73.25	75.00
22	7.50	10.00	20.98	28.25	41.50	60.75	71.00	73.00
26	14.49	31.75	48.00	53.50	56.62	47.12	59.00	60.50
	56.86	133.50	262.96	357.25	486.24	664.24	694.87	723.47
Mean	5.68	13.35	26.29	35.72	48.62	66.42	69.48	72.34

Mean total growth = 72.34 ± 6
σ = 29.7
C = 41.

Check Series

Average total growth at different periods.

Tree No.	Apr. 24	May 4	May 14	May 20	June 2	June 29	Aug. 8	Nov. 10
21	2.75	10.75	20.25	36.50	47.25	48.75	49.25	52.75
37	6.25	11.75	14.75	16.00	18.50	30.25	30.87	30.87
36	2.25	25.75	59.75	68.75	41.00	84.25	85.12	92.87
35	—	.25	5.75	11.50	24.75	23.00	23.50	23.87
34	1.25	1.75	2.00	2.50	2.50	3.00	3.50	3.50
33	8.12	18.25	25.25	46.25	60.50	67.50	66.50	68.25
32	1.75	3.25	14.49	20.25	24.50	26.15	26.75	28.00
31	9.62	18.75	30.00	36.00	48.75	45.34	52.75	53.75
	31.99	90.50	172.24	237.75	267.75	328.24	338.24	353.86
Mean	3.99	11.31	21.53	29.71	33.47	41.03	42.28	44.23

$$\text{Mean total growth} = 44.23 \pm 6.3$$
$$\sigma = 26.5$$
$$C = 59.9$$

In a comparison of differences in average total growth for each series it will be found that there is a significant difference between the Nitrate of Soda Series and all others. As an example this comparison between the Nitrate of Soda Series and the Ammonia Sulphate Series is given.

Nitrate of Soda Series mean $= 72.34 \pm 6.$

Sulphate of Ammonia Series mean $= 51.31 \pm 4.$

$$\text{Difference} = 21.03 \pm \sqrt{36+16}$$
$$= 21.03 \pm 7.2$$

As the difference is practically three times its probable error, it may be considered as significant.

On the other hand by this method there is not any significant difference between the Sulphate Series and the No Nitrogen or Check.

By the modified method of Student as used by Love and Brunson (11), which is more applicable to small numbers, odds of 30:1 in favour of the Ammonium Sulphate over the No Nitrogen were obtained. By arranging each series in ascending order and making comparisons in this manner the following odds are obtained by the Love and Brunson method. As an example of the application of this method the data for the comparison between the Nitrate of Soda Series and the Ammonium Sulphate Series are appended.

Comparison between Nitrate of Soda and Ammonium Sulphate Series by Love and Brunson Method.

	Nitrate of Soda	Ammonium Sulphate	Gain Nitrate of Soda over Ammonium Sulphate	D	D^2
1.	10.12	9.00	+ 1.12	— 20.91	437.21
2.	37.75	28.75	+ 9.00	— 12.03	144.72
3.	60.50	41.00	+ 19.50	— 2.53	6.40
4.	63.62	47.75	+ 15.87	— 5.16	26.62
5.	73.00	50.37	+ 22.63	+ 1.60	2.56
6.	75.00	62.00	+ 13.00	— 8.03	64.48
7.	89.37	63.25	+ 26.12	+ 5.09	25.90
8.	99.12	64.25	+ 34.87	+ 13.84	191.54
9.	102.37	68.75	+ 33.62	+ 12.59	158.50
10.	112.62	78.00	+ 34.62	+ 13.59	184.68
			210.35		S = 1242.61

$$Z = \frac{21.03}{11.15} = 1.89 \text{ taken as } 1.9$$

$$\sigma = \sqrt{\frac{1242.61}{10}} = 11.15$$

Mean diff. = 21.03

Odds = 9999 : 1

Odds Obtained by Love & Brunson Method

Odds in favour of Nitrate of Soda over Ammonium Sulphate	= 9999 : 1
Odds in favour of Ammonium Sulphate over No Nitrogen series	= 30 : 1
Odds in favour of No Nitrogen series over Total Check	= 90 : 1

From these odds the only signicant difference is that of the Nitrate of Soda Series over all others, with a possible significance between the No Nitrogen and Ammonium Sulphate Series over the Check.

Graph No. 1 portrays the trends of the four series in growth response at the different periods and it is interesting to note the parallelism of the Nitrate line, the Check and the No Nitrogen up to May 14, accompanied by the lag of the Sulphate line which began to parallel and exceed the No Nitrogen on June 29.

The Root System

At the end of the season, two trees representative of the sample in each series were lifted, washed free of the substratum and the roots separated from the trunk, weighed and photographed. The attached illustration shows the weights of one set of these roots and brings out some of the characteristic differences. The Check Series was characterized by a sparse root system, evenly distributed through the pot. The No Nitrogen Series while possessing a large number of feeding roots did not weigh much more than the Check Series. Its root system was confined more to the top half of the pot.

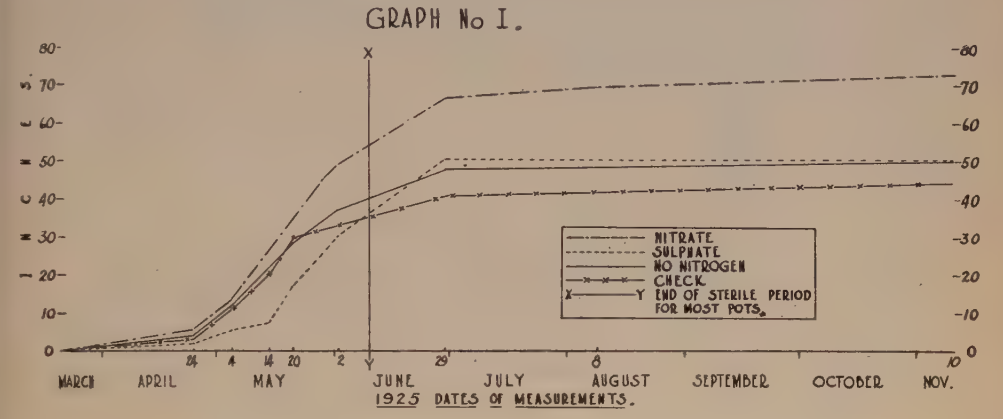
In the Sulphate of Ammonia Series there was a noticeable comparative absence of roots at the bottom of the pot, with a large number of newly formed roots on the top two inches. This would indicate a rapid root formation at the latter part of the season after the admission of nitrifying organisms.

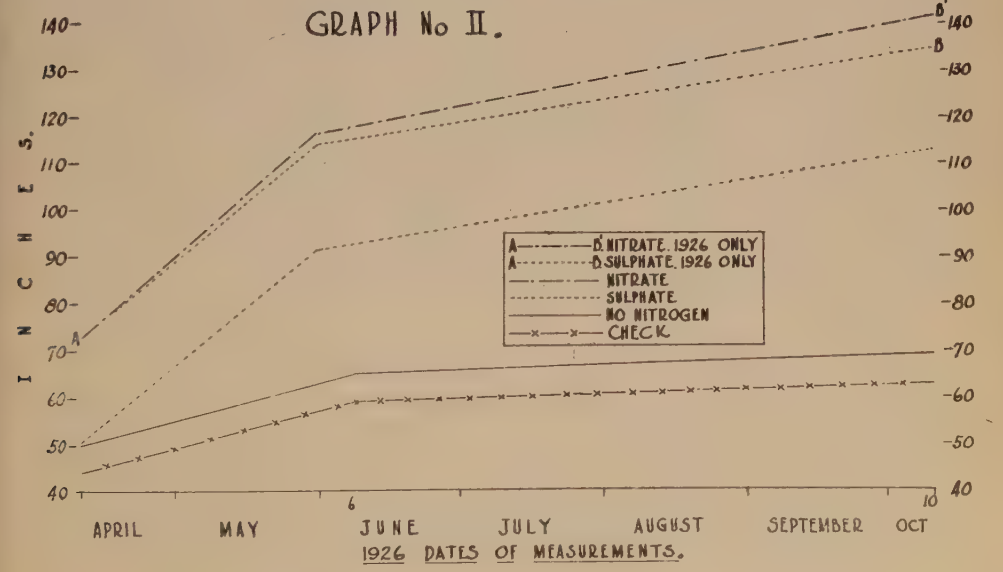
In the Nitrate of Soda Series the root system was well and evenly distributed and contained many more fine feeding roots than the other series.

Discussion of the 1925 Results.

From this data there is certainly no indication that apple trees are capable of using ammonia as a direct source of nitrogen. Apparently a certain degree of toxicity existed in the sulphate series as it not only failed to respond as the Nitrate Series but for a time lagged behind even the Total Check. As there was an increased amount of sulphate ion in the ammonium sulphate solution as applied, this toxicity might be considered due to that alone. The results from these same trees the 2nd year, (minus the ones used for analytical purposes) indicate, however, that the increased sulphate ion had little effect as will be observed from the following data.

It will be recalled that by the end of the first season the sulphate pots showed positive results from tests for nitrifying organisims. As the results for 1926 showed the Sulphate Series practically equal to the Nitrate Series for total seasonal growth response, this would lead us to conclude that the toxicity of 1925 was due to the absence of oxidation of the ammonium sulphate, and to suspect that the trees had been able to absorb some of the ammonium sulphate but not utilize it efficiently.





Results of the 1925 trees in 1926.
Average total new growth at different periods in 1926.

Ammonium Sulphate Series.			*No Nitrogen Series*		
Tree	June 6	Oct. 10	Tree	June 6	Oct. 10
2	30.12	53.36	12	6.50	8.00
4	60.50	72.75	13	24.75	30.00
5	68.12	72.12	14	14.25	19.60
6	50.25	70.36	15	25.36	25.36
7	5.00	23.25	16	5.50	11.00
8	35.25	53.60	18		9.50
9	46.60	69.00	19	10.50	11.00
10	61.25	69.75	20	14.12	33.84
	357.09	484.19		100.98	148.30
Means	44.64	60.52	Means	12.63	18.53

Nitrate of Soda Series			*Check Series*		
Tree	June 6	Oct. 10	Tree	June 6	Oct. 10
30	58.50	67.60	21	7.12	11.12
28	76.50	95.60	37	14.50	14.50
27	34.84	63.00	36	13.12	13.50
25	32.00	50.12	35	6.50	14.75
24	65.25	85.50	34	41.84	43.75
23	39.25	66.25	32	6.50	16.60
22	19.75	61.75			
26	41.50	69.50		89.58	114.22
	367.59	559.32	Means	14.93	19.04
Means	45.94	69.92			

From these tables it will be seen that there is little difference between the Nitrate Series and the Sulphate Series. Making comparison by the Love and Brunson method we find that the odds for these comparisons are as follows, the details for the Ammonium Sulphate and Nitrate of Soda Series being given:

1926 Results—1925 Group.
Average total growth.
Ammonium Sulphate vs. Nitrate of Soda Series.

Tree	Ammon. Sulphate		Nitrate of Soda	Gain of Nit. of Soda over Ammon. Sulph.	D	D²
7	23.25	25	50.12	26.87	17.48	
2	53.36	22	61.75	8.39	1.00	
8	53.60	27	63.00	9.40	.01	
9	69.00	23	66.25	— 2.75	6.64	
10	69.75	30	67.60	— 2.15	7.24	
6	70.36	26	69.50	— .86	8.53	
5	72.12	24	85.50	13.38	3.99	
4	72.72	28	95.60	22.85	12.46	
				80.89		

Mean of Diff. = 9.39

$S = 646.99$

$\sigma = \sqrt{\frac{646.9}{8}} = 8.9985$

$Z = \frac{9.391}{8.9985} = 1.0436$

Odds = 1 to 70.4 in favour of Nitrate of Soda.
Odds in favour of Nitrate of Soda over Ammonium Sulphate = 70:1.
Odds in favour of Ammonium Sulphate over No Nitrogen Series = 3332:1.
Odds in favour of No Nitrogen Series over Check = 5 to 1.

While this does not give any information as to the speed of the availability of Ammonium Sulphate under orchard conditions, it is of interest to note that here was a pure sand, devoid of organic matter which after sterilization and without any artificial inoculation acquired sufficient organisms to oxidise Ammonium Sulphate to a high degree of efficiency for plant use.

The 1926 Group

In 1926 a duplicate experiment of that described under 1925 was started with trees of the same age. In this series the nutrients supplied were the same as in 1925 but instead of only four applications the solution was applied more frequently. A twelve inch pot contains 19,826 grams of the dry substratum, so the applications of nutrient solution, using the same formula as in 1925 but with different dilutions, gave for each series the following periodic total salt concentrations calculated on the dry weight basis of the sand:

Nitrate Series	.0117%
Ammonia Series	.010%
*Cyanamide Series	.009%
No Nitrogen Series	.007%

*As noted in this list of salt concentrations, a new series giving cyanamide treatment was included. In addition a series in best greenhouse soil mixture was also added.

These concentrations gave the following total amounts of each element per pot for the season:—

	Ammonia Series	Nitrate Series	Cyanamide Series
Magnesium	.50 gms.	.50 gms.	.50 gms.
Potassium	1.36 "	1.36 "	1.36 "
Phosphorus	.56 "	.56 "	.56 "
Calcium	2.09 "	2.09 "	5.28 "
Sodium	— "	2.53 "	— "
Nitrogen	1.42 "	1.54 "	2.85 "
Sulphur	2.89 "	1.24 "	.71 "
Chlorine	2.97 "	2.97 "	.70 "
Totals	11.79 gms.	12.79 gms.	11.96 gms.

It will be observed that the total amount of elements applied in this instance is just about double the amount applied to the 1925 series. As will be pointed out later this quantity proved toxic in all cases, so that the optimum amount of nutrient solution for an apple tree under these conditions evidently lies below the concentrations reported for 1926.

The following summary of notes from field records taken during the season will give the qualitative data available:—

Summary of Notes for 1926 Group

Soil Treatment—Trees in advance of any of the other series, wood heavier, growth more vigorous, leaves larger. This series continued to be outstanding throughout the season, having heavier blossom and making stronger growth.

Check—This series though not as good as the previous series showed fair growth as compared with the other series. Two of the trees did not

break their leaf buds. For a certain time this series showed equal growth with those obtaining nutrient solution but after a certain period the lack of food made itself felt and was demonstrated by a lighter foliage and less vigorous growth. Initial growth considered to be due to stored-up food.

No Nitrogen—In this series three trees did not break their leaf buds. The rest of this series showed good vigorous growth. For a considerable period, even into mid-summer, there was no appreciable difference between this and the Sodium Nitrate series. At present, however, it is to be noted that in this series the foliage is lighter, the wood less heavy and the new twig growth less.

Sodium Nitrate—With the exception of the Soil series it is undoubtedly the best series in the Experiment. Three trees did not break their leaf buds. Foliage dark green, wood heavier and twig growth greater.

Cyanamide—The initial growth in this series was not as good as the Sodium Nitrate or No Nitrogen series. The leaf buds unfolded at a later date and the rate of growth was not so vigorous.

After several applications of solution, about the end of July the trees began to give evidence of signs of distress. The leaves and leaf stalks turned brown, shrivelled up and died. This was true for practically every tree in the series. From these results it was assumed that the nutrient supplied was exercising a toxic effect.

Ammonium Sulphate—Eight trees in this series did not break their leaf buds. The trees in this series remained dormant for a considerable period after the other trees had unfolded their leaf buds. The growth was very weak—very little new wood being formed.

Total Growth Measurements of 1926 Group

To save space only the means of each series are here given. In each case, the series included fifteen trees; two sets of means are given (1) being the mean growth when the fifteen trees are considered, the other (2) being the mean when the trees which did not break are withdrawn.

Summary of Average Growth Responses in 1926 Group.

Series	25-6-26	13-7-26	10-8-26	20-10-26
Ammonia (1)	.43	.624	4.88	8.94
" (2)	.92	1.330	10.46	19.17
Nitrate (1)	4.33	7.88	12.52	16.02
" (2)	5.91	10.76	17.07	21.85
Cyanamide (1)	—	—	2.26	9.45
" (2)	—	—	2.83	11.68
Soil (1) & (2)	32.37	46.54	58.85	68.40
No Nitrogen (1)	6.49	11.48	16.31	18.81
" (2)	6.95	12.32	17.47	20.15
Check (1)	7.32	10.70	12.61	14.26
" (2)	10.32	14.98	17.65	19.95

The outstanding result from this year's work was that in all cases the nutrient solutions appeared to be somewhat toxic as compared with the Soil series which did not receive any solution. It is of further interest to note that the Check series which did not receive any solution made only an average growth of 19.95 inches (when the trees not breaking were deducted), whereas in the 1925 group this same series averaged 44.23 inches total growth. As the 1925 group had a growing period from March 16 to

November 10 (being in the greenhouse from March to June) as compared with a season of from May 15 to November 10 for the 1926 group, it is probable that this extra two months of growing season had the effect of more than doubling the total growth of the trees.

As further evidence that the solution applied in 1925 was somewhere near the optimum in the Nitrate of Soda series the growth response of the Soil series in 1926 is valuable. The Nitrate of Soda series in 1925 gave a response of 72.34 inches while the Soil series in 1926 gave a response of 68.40 inches. Of course the effect of the longer season is not known and an attempt to determine this is now under way.

Comparison of the Ammonia and Nitrate Series by the Love and Brunson Method.

As the main object of the experiment was to determine the comparative availability of Nitrate of Soda and Ammonium Sulphate without nitrification the direct comparisons of the series other than these two will be omitted.

Comparison between Ammonium Sulphate and Nitrate of Soda Series—1926 Group.

Nitrate Series	Ammonium Sulphate Series	Gain of Nit. of Soda over $(NH_4)_2SO_4$	D	D^2
1.00	—	+ 1.00	7.75	
1.12	—	1.12	7.63	
5.25	—	5.25	3.50	
12.60	—	12.60	3.85	
17.12	2.50	14.62	5.87	
14.75	7.00	7.75	1.00	
24.25	15.25	9.00	.25	
29.84	19.84	10.00	1.25	
36.12	29.12	7.00	1.75	
40.25	29.25	11.00	2.25	
58.12	31.25	16.87	8.12	
		96.21		S. = 256.49

Mean diff. $= + 8.75$

$$\sigma = \sqrt{\frac{256.49}{11}} = 4.83$$

$$Z = \frac{8.75}{4.83} = 1.81$$

P = .99978 + therefore odds = 4999 to 1 in favour of Nitrate of Soda over Ammonium Sulphate.

The odds as in the 1925 group are infinitely in favour of Nitrate of Soda over Amonium Sulphate.

Other odds derived by this method for the 1926 group are:—

6.5 : 1 in favour of No Nitrogen over Check.

22.9 : 1 in favour of Nitrate of Soda over Check.

9999: 1 in favour of Soil Series over Check.

6.0 : 1 in favour of Ammonium Sulphate over Cyanamide.

It is easily seen from this that none of the nutrient solutions showed any appreciable advance over the Check; in other words all solutions can be considered as having had a toxic influence at the concentrations used under these conditions. Nitrate of Soda had by far the least toxic effect of any of

the nitrogenous group, and thus far no evidence of the availability of Ammonium Sulphate under sterile soil conditions has been accumulated.

Summary

In summarizing the results from the two seasons' work with three separate groups of growth responses, viz.:—

1st year results from 1925 group
2nd year results from 1925 group.
1st year results from 1926 group.

the following evidence appears:—

(1) These experiments have failed to demonstrate that nitrogen is available for apple trees in the form of Ammonium Sulphate.

(2) As soon as nitrifying organisms are present in the substratum the Ammonium Sulphate Series appeared to give about as good growth response as did Nitrate of Soda.

(3) The root development of the 1925 Series 1st year, bore out the deductions from the growth responses of the top.

(4) When applied in quantities which appear to be above the optimum concentration toxicity existed in the order named:—

Most toxic—Cyanamide.
Next toxic—Sulphate of Ammonia.
Least toxic—Nitrate of Soda.

indicating that under conditions where nitrifying bacteria are not present, Nitrate of Soda is a less dangerous proposition than either of the other two nitrogenous compounds.

(5) From the evidence obtained in these experiments it would appear that Sulphate of Ammonia becomes available on a very poor sand when nitrifying organisms are present.

Horticultural Division,
Central Experimental Farm, Ottawa.

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PLATE I.

Roots from the different series, showing weight of each and root distribution. (*Photo by F. T. Shutt.*)

THE CYTOLOGY OF SPECIES HYBRIDS IN WHEAT

W. P. Thompson

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The different species of wheat and their relatives and hybrids present a very interesting situation from the standpoint of cytology. And, as in so many other cases, the cytological work has thrown much light on the results, particularly the disappointing ones, obtained in genetical studies and in the practical breeding of wheat. The cytological studies which have recently been published in a number of scattered papers are here brought together and briefly reviewed.

Pure Species

Sakamura (6) and Kihara (1) were the first to report correctly the numbers of chromosomes in the different species of Triticum and to describe them accurately. Their work has been confirmed by a number of investigators (7, 9, 11, 14, 15). From Table 1 it may be seen that there is a very interesting series of relationships amongst the chromosome numbers of the different species. All species have a multiple of 7, and they fall naturally into three groups depending on whether the reproductive cells contain 7, twice 7, or three times 7 chromosomes. The body cells, of course, have twice these numbers. It is important to note that this classification is the same as the one based on botanical characters and agreed upon by botanists before the chromosomes had been studied. The three groups of species may be referred to as the einkorn (7-chromosome), emmer (14), and *vulgare* (21) groups. Rye, also, has 7 chromosomes in its reproductive cells.

Table I.

SPECIES	CHROMOSOME NUMBER	
	Body Cells	Reproductive Cells
Einkorn, T. monococcum	14	7
Emmer, T. dicoccum	28	14
Durum, T. durum	28	14
Rivet, T. turgidum	28	14
Polish, T. polonicum	28	14
Wild, T. dicoccoides	28	14
Common, T. vulgare	42	21
Club, T. compactum	42	21
Spelt, T. spelta	42	21
Rye, Secale	14	7

Presumably the ancestral forms had a single set of 7 and in the distant past one or more duplications and triplications occurred which resulted in the progenitors of the present groups. Exactly how the multiplications occurred is not, of course, known, but methods can easily be imagined. It has been suggested (4) on botanical grounds that the *vulgare* series (which has 21) may have arisen through hybridization of the emmer series with Aegilops, some forms of which have 14.

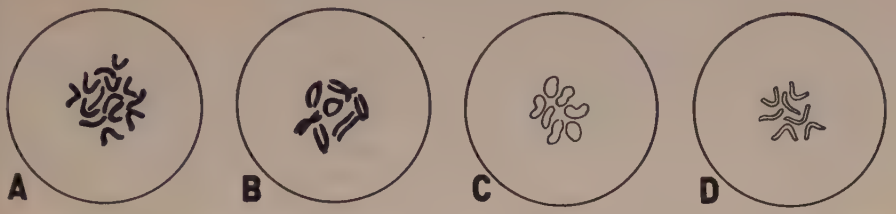

FIGURE 1. *T. monococcum* (Einkorn). A, cell from root-tip with 14 chromosomes; B, first reduction division, 7 mated pairs of chromosomes; C, pairs fused to form 7 bivalent chromosomes; D, second reduction division, 7 single chromosomes.

The 14 chromosomes, of the vegetative cells (root-tip) of einkorn are shown in figure 1A. They are long, slender and much curved. (For the sake of clearness most of the illustrations in this paper are somewhat diagrammatic). In figure 1B is shown a pollen grand-mother cell. The 14 chromosomes have mated in 7 pairs. The members of each pair fuse to form a single short, stout, *bivalent* chromosome (fig. 1C). These then divide (first reduction division) so that the mother cell of the pollen grain receives 7 single chromosomes. When it divides to form the pollen grains (second reduction division) each of the 7 divides normally. The pollen grains therefore contain 7 *univalent* chromosomes. When egg and sperm fuse at fertilization the number 14 is again restored and is found in all vegetative cells.

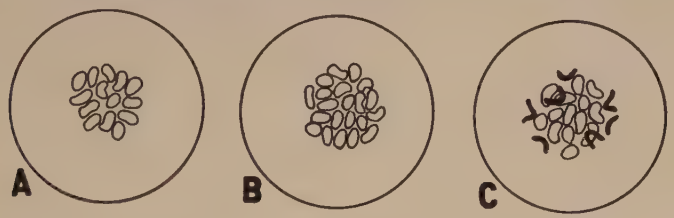

FIGURE 2. A. *T. durum*, first reduction division in pollen grandmother cells showing 14 bivalent chromosomes; B, same stage in *T. vulgare* showing 21; C, same stage in hybrid *vulgare* x *durum* showing 14 bivalents and 7 univalents.

Figures 2A and 2B show the 14 and 21 bivalent chromosomes at the first reduction division in the reproductive cells of *T. durum* and *T. vulgare* respectively.

HYBRIDS BETWEEN 14– AND 21– CHROMOSOME SPECIES.

When any member of the emmer series is crossed with any member of the *vulgare* series (Kihara 2, Sax 7) the F_1 has 35 (14+21) chromosomes in all its body cells, and these behave normally. But in the formation of the reproductive cells in this hybrid the mating process cannot be carried on as usual. Figure 2C shows what happens in *durum* x *vulgare*. The 14 *durum* chromosomes mate with 14 of the *vulgare* ones, leaving the remaining 7 *vulgares* unmated. The 14 appear as stout bivalents (represented clear) and the extra 7 *vulgares* which find no mates appear as slender univalents (represented black) like those of vegetative cells. Evidently each chromosome has a particular mate and the extra 7 from the *vulgare* parent are unable to mate amongst themselves.

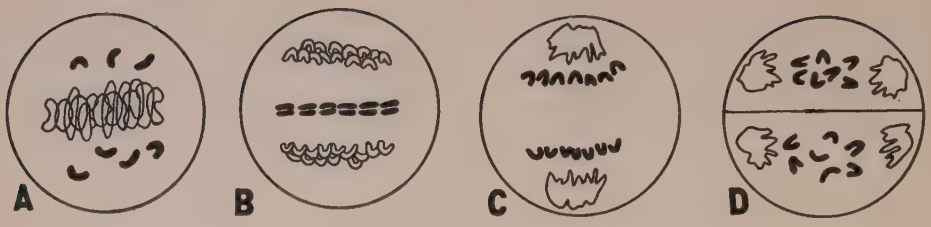

FIGURE 3. The hybrid between 21-and 14-chromosome species: A, B, C, side views of successive stages in first reduction division showing behaviour of the 14 bivalents and 7 univalents; D, late second division showing the scattering undivided univalents.

When the 14 double chromosomes move into the equatorial position for division the 7 single ones lag and are found in various positions outside the plate or at the edge of it (fig. 3A). After each bivalent has divided into its two components and these have pulled apart towards the ends of the cells, the 7 univalents move into the equator and split equationally (fig. 3B). Though their halves lag considerably behind the 14, all of them usually reach the new nucleus (fig. 3C), so that each of the resulting cells receives 14 chromosomes (halves of bivalents) and 7 half-chromosomes (halves of univalents. At the next (second reduction) division, which produces the pollen grains, the 14 divide normally but the 7, having already divided, cannot do so again and lag behind the others (fig. 3D). They simply wander at random to either end so that the pollen grains may receive any number from 14 to 21 (14+0 to 7). Most of them will receive 17 or 18. Their behaviour in later generations will be taken up after the F_1 of other crosses is described.

HYBRIDS BETWEEN 14– AND 7– CHROMOSOME SPECIES.

The behaviour in the cross between a 14– and a 7– chromosome species has been described by Sax (7) and by Thompson (11). The account of the latter which differs materially from that of the former is followed here. In the hybrid between *turgidum* (14) and einkorn (7) the number of mated pairs is not constant but varies from 3 to 7, and the unmated ones correspondingly from 15 to 7. From Table 2 it may be seen that twice the number of bivalents plus the number of univalents always equals 21, the sum of the numbers of the parents. Evidently all the 7 einkorn chromosomes sometimes find mates among the 14 of *turgidum* and in that case 7 (14–7) of the latter are left unmated. But usually 1 to 4 of the einkorn ones are unable to find mates and the number of unmated ones is correspondingly increased. The commonest number of mated pairs is 5 and of unmated ones 11 (fig.4A).

TABLE II.

Bivalents	Univalents
3	15
4	13
5	11
6	9
7	7

FIGURE 4. A and B, the 14 x 7 hybrid; C and D 21 x 7; E and F wheat x rye (21 x 7). See text.

It seems that since the original duplication which produced the 14–chromosome form, the chromosomes have become so differentiated that mating is difficult and often fails. This is further indicated by the fact that the mating is never as intimate as in pure species.

The behaviour is in other respects similar to that described for the 21 x 14 cross (fig. 4B). Thompson (unpublished results) has found that the hybrids between einkorn and other 14–chromosome species present the same situation as the hybrid between einkorn and *turgidum*.

HYBRIDS BETWEEN 21– AND 7–CHROMOSOME SPECIES.

Most investigators report negative results in attempts to make the widest wheat cross—that between a 21– and a 7– chromosome species. Melburn and Thompson, however, succeeded in growing a single hybrid between T. *spelta* and einkorn and have described its cytological behaviour (3).

The number of mated pairs at the first reduction division varies from 0 to 5 and is usually 3 (fig. 4C). This means that always at least 2, usually 4, and sometimes all 7 of the einkorn chromosomes fail to find mates among those from *spelta*. Evidently the evolutionary differentiation has gone further than in the previous cases and the mating of chromosomes is still more difficult. The number of unmated ones depends, of course, on the number which mate, the sum of the former plus twice the latter always equalling 28, the sum of the parental numbers. Thus the univalents vary in number from 18 to 28.

The behaviour of some of the univalents is always abnormal. After the components of the mated pairs pull apart, some of the univalents move into the equator and divide while others remain near the ends of the cell (fig. 4D.) until their fellows arrive after dividing. Thus the new nuclei consist of (1) univalent chromosomes which have not divided, (2) halves of bivalents, and (3) halves of univalents which have divided. The number of each constituent is quite variable. Owing doubtless to all these abnormalities the hybrid is quite sterile.

Hybrids between Common Wheat and Rye.

Rye has the same chromosome number (7) as einkorn wheat, but all attempts to cross them have proved unsuccessful. Nevertheless an occasional cross has been made between *vulgare* wheat and rye, and with one variety of wheat the cross is easily made (10). So far as chromosome numbers are concerned this cross is the same as that just described (*spelta* x einkorn) but it is evidently quite different in regard to chromosome constitution. Kihara (2) and Thompson (10) have described the cytology of the wheat-rye cross.

The most striking feature is the usual entire absence of chromosome mating. In the reproductive as in the vegetative divisions 28 (21+7) single univalents appear (fig. 3E). Evidently the affinity of *vulgare* chromosomes is less for rye even than for einkorn. Occasionally 1 or 2 and very rarely 3 pairs succeed in mating, but in the great majority of cases there are no bivalents at all. Moreover the 28 univalents behave in quite unusual fashion. They never arrange themselves in an equatorial plate and few if any of them divide. They simply scatter haphazardly to the ends of the cell (fig.3F). Hence the pollen grains receive approximately 14 chromosomes but the number varies within wide limits since the process is quite irregular and many lag so much that they fail to reach the new nucleus. The hybrid is consequently almost but not quite completely sterile.

The entire absence of mating shows that in pure species of wheat every chromosome must have a particular mate. Since the original 7 have been triplicated there must be in the reproductive cells of *vulgare* 3 of each kind. It might be expected therefore that any one of each set of 3 could mate with any other one. But since they fail to do so when they have an opportunity in wheat-rye hybrids, it is evident that sufficient differentiation has occurred since the original triplication to confine mating to particular pairs.

Hybrids between *vulgare* wheat and another related genus, Aegilops, have been investigated by Sax (8) and by Percival (5). The results are somewhat conflicting, the former reporting regular behaviour with 7 mating pairs, and the latter highly abnormal and variable behaviour.*

Comparison of the Different Hybrids

Some of the results for the different crosses are summarized in the following table in order to make comparison easier. It is evident that the different crosses can be arranged in a regular series according to the chromosome

Table III.

	Vulgare x Emmer 21 x 14	Emmer x Einkorn 14 x 7	Vulgare x Einkorn 21 x 7	Vulgare x Rye 21 x 7
Number of mated pairs	14	3 to 7 usually 5	0 to 5 usually 3	0 to 3 usually 0
Number of unmated	7	18–7	28–18	28–22
Number of unmated that split at first division	all	usually all	most	few or none
Loss of chromosomes through lagging	little	little	some	much
Fertility	good	slight	none	almost none

*Gainer and Aase (Amer. Jour. Bot. 13, 1926) confirm the report of Sax, and in addition state that in hybrids between Aegilops and 14-chromosome wheats there is no mating of chromosomes.

affinities which they exhibit, as judged by the amount of mating, the abnormalities in the behaviour of the univalents and the loss of chromosomes through lagging. In order of decreasing affinity the series runs (1) *vulgare* x emmer, (2) emmer x einkorn, (3) *vulgare* x einkorn, (4) *vulgare* x rye. There is a corresponding series in respect to fertility and botanical relationships.

Later Generations of Hybrids between 21– and 14– Chromosome Species.

The only type of cross which has been investigated cytologically beyond the F_1 is that between *vulgare* and emmer groups (21 x 14). Genetically this cross has been much studied for economic reasons. But the practical results have been disappointing. The characters of the two parents tend to be inherited as blocks, so that it is difficult to obtain a combination of *vulgare* characters with particular *durum* or *dicoccum* ones (Sax 5, Thompson 9, 13). The great majority of the hybrids in later generations are *vulgare*-like or emmer-like. The reason for this lies in the peculiar chromosome behaviour.

We have already seen that the reproductive cells of the F_1 contain from 14 to 21 chromosomes since they receive 14 bivalents and from 0 to 7 univalents. Those with the intermediate numbers will, of course, be by far the most numerous. It is easy to calculate the proportion of plants to be expected in F_2 with various chromosome numbers and combinations of bivalents and univalents. But the actual results are very different from the expected ones. A much larger proportion of the F_2 have one or the other of the parental numbers than is to be expected and the intermediate numbers which do appear are not constant in later generations. The hybrids have either (a) 14 bivalents plus 0 to 7 univalents, or (b) more than 14 bivalents plus enough univalents to make the total number 21 (Kihara 2, Thompson and Hollingshead 13). If there are more than 14 bivalents there must be enough univalents to make up at least one complete set of 7, the basic number in wheat Those in group (a) tend to revert in later generations to the number 14, characteristic of emmers; those in group (b) to the number 21, characteristic of *vulgare*. The cause of the absence of the intermediate numbers is doubtful. But it seems that the only viable and stable chromosome conditions are those of the parents. It has been suggested that one or more of the basic sets of 7 make properly balanced conditions, and that the absence of members of a set results in a condition of unbalance which is injurious.

These results explain in part at least the genetic difficulties. The emmer-like hybrids are those in the group which revert to the 14-chromosome condition; the *vulgare*-like ones are those in the group which revert to 21. It seems impossible to establish a stable race intermediate in chromosome numbers. Whether it will be possible to detach one or a few economically valuable emmer characters and associate them with *vulgare* one remains to be determined by large-scale experiments. A fact which appears hopeful in this connection is that a 14– chromosome variety of wheat which possesses certain *vulgare* characters has been cultivated for a long time (Thompson 12).

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University of Saskatchewan,
Saskatoon, Sask.

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LA METHODE PHYTOMETRIQUE EN ECOLOGIE

Reverend Pere Louis Marie,

Institut Agricole d'Oka, La Trappe, P. Q.

Il y a longtemps que l'homme a observé un jeu d'association entre les plantes et les animaux d'une part, et les lieux qu'ils habitent d'autre part. Les voyageurs de tous les siècles , engeance qui a beaucoup vu, même ceux qui parurentavant Lamark et Darwin, avaient été excités à ce problème, source d'évolution. Cependant, ce n'est que depuis un quart de siècle à peine, que s'organisent sur une base quantitative les recherches concernant ces rapports de "plantes à milieux." Durant les nombreux siècles où l'on ne fit que constater la présence des phénomènes, leurs seules qualités, sans souci d'en prendre la mesure exacte, d'en faire le dosage, cette science d'observation demeura à l'état d'embryon, n'ayant pas plus de forme que de nom. Il en fut du reste ainsi, dans les divrs domaines des sciences expérimentales, pour plus d'une autre discipline. Et ce que Claude Bernard affirma de la Biologie s'applique à toute loi scientifique: "Si en Biologie, dit-il, on veut arriver à connaître les lois de la vie, il faut de plus fixer numériquement les relations d'intensité dans lesquelles les vivants sont les uns par rapport aux autres."

Le moment de passage, dit le Fr. Marie-Victorin, de la conscience banale des phénomènes à leur connaissance scientifique est le passage de la notion qualité à la notion quantité. Exemples:

a) *L'astronomie* succéda à l'astrologie le jour où le premier observateur, ne se bornant plusà la constatation du déplacement des astres, mesura leurs angles de déplacement, la durée respective des diverses phases de la lune, etc. C'est la considération de longues séries d'observations numériques de ce genre qui conduisit graduellement, par voie d'approximations successives, Copernic, Képler, Newton à l'édification progressive des lois numériques de l'astronomie et de la gravitation.

b) *La chimie* succéda à l'alchimie le jour où les observateurs, ne se contentant plus de constater les propriétés chimiques des corps, firent intervenir dans l'étude des réactions chimiques la mesure des poids et des volumes des corps réagissants. C'est ainsi que l'on est arrivé progressivement à l'établissement des lois numériques célèbres de Proust (Lois des proportions définies), de Dalton (Lois des proportions multiples) de Gay-Lussac (Loi de combinaison des gaz), D'Avogadro et d'Ampère (Loi des concentrations gazeuses moléculaires).

F. E. Clements, qu'il faut placer tout près de Warming en Biologie, fut l'un des pères américains de la nouvelle science qui présentement nous occupe; dans ses "Research Methods in Ecology," 1915, il nous donne l'excellent conseil qui suit: "Any serious endeavor to find in the habitat, those causes which are producing modification in the plant.....cannot stop with the factors merely. The next step is to determine the quantity of each. It is not sufficient to hasard a guess, a rough estimate of it. Habitats differ in all degrees and it is impossible to institute comparisons between them without

an exact measure of each factor.....The employment of instruments of precision is clearly indispensable..... and the student that intends to strike at the root of the subject..... must familiarize himself with instrumental methods."

A cette science à peine nommée, une méthode fut donc nécessaire pour opérer avec précision. Aussi les premiers essais méthodiques "ante partum" remontent-ils à plus de soixante-cinq ans.

Mentionnons quelques expérimentateurs:
Sachs (1859); Mayer (1875); Bonnier (1890), experiénces classiques: parallèle entre Topinambour et Pissenlit cultivés dans la plaine et ceux cultivés en montagne; Gain (1895); Clements (1900-20); Hildebrand (1921); Clements et Lutjeharins (1921-22; Clements et Goldsmith (1919-23); Lutjeharins (1924); Clements et Weaver (1924).

Les méthodes des savants ci-dessus mentionnés se nuancent graduellement depuis "le point de vue qualitatif pur" au "quantitatif math ématiquement exact."

Pour obtenir cette précision requise, on eut recours aux instruments météorologiques; mais ces instruments ne donnaient que la *valeur absolue* des facteurs ambiants, non pas leurs relations avec la plante; de tels instruments peuvent par exemple dire le degré de froid, d'humidité, de lumère, de chaleur affectant un jardin; la plante seule peut nous dire la quantité d'influence qu'exerce sur son développement, pour le hâter ou le retarder, chacun de ces facteurs. Par ailleurs les instruments trop sensibles donnent parfois une fausse signification aux résultats qu'ils indiquent. Leur aide est nécessaire, mais *jamais il ne convient de l'utiliser sans un contrôle vivant.* Les plus utiles de ces instruments sont:

1o—Pour l'atmosphère: l'hygrothermographe, le solographe, l'atmomètre, l'anémomètre, l'hydromètre (rain-gage).

2o.—Pour le sol: instruments à fins parallèles, surtout le thermographe et le aéromètre. L'analyse chimique du sol a aussi ses appareils.

A côté de ces index artificiels, les plantes sauvages furent de tous temps des phytomètres tout indiqués; principalement celles qui, bien franchement, manifestent des affinités ou des reépulsions pour la chaux ou la silice et que l'on appelle pour cela silicicoles ou calcifuges, calcicoles ou silicifuges. On s'adressa en conséquence aux plantes soient cultivées, soient sauvages, à qui l'on demanda une mesure standard des influences ambiantes.

Pour ce genre d'expériences, il faut une plante vigoureuse, a croissance facilement contrôlable, se prêtant commodément au mesurage et autres manipulations, que l'on nomme phytomètre; (phuton = mêtron). Les fèves et les pois, les topinambours et les soleils sont d'excellents phytomètres.

L'emploi de plantes cultivées est préférable, si l'on veut mesurer la valeur des facteurs d'un potager ou de toute autre terre cultivée d'une façon intensive ou extensive. Mais les plantes sauvages sont plus aptes à rendre compte des habitats naturels (forêts, pacages marais, tourbières,savanes ...). Le phytomètre, dans ce dernier cas, sera ordinairement *naturel,* si les plantes dont on se sert sont des habitants du lieux soumis à l'étude, demeurées dans la position créée par leur vie sauvage.

Si, au contraire,—et c'est ce que nous avons lorsque nous l'employons une plante cultivée,—le phytomètre est un étranger transplanté pour le besoin de l'étude, il est dit *artificiel.* Ces plantes, témoins artificiels, seront:

1) *des phytomètres de contrôle*: plantes standards semblables entre elles par leurs formes, leur taille et leur susceptibilité; contenues dans des pots que l'on peut transporter rapidement d'un lieu à un autre, pour faire les comparaisons voulues. Ces pots peuvent être de fer blanc, de zinc ou de fer galvanisé, imperméables en tous cas; leur grosseur dépend du système de la racine et de la distance de transport.

2) *des phytomètres libres*: a) plantes à l'âge adulte pour l'étude des facteurs physiques; b) en graines pour celles des facteurs biologiques (compétition, animaux) :ces plantes sont soumises au complexe des facteurs du lieu.

3) *des phytomètres climatiques*: cultivés en pots scellés ou non suivant la partie du climat que l'on veut considérer et la fonction qui lui est soumise. Ainsi on scellera l'ouverture du pot pour calculer le coefficient respiratoire ou celui de l'absoption. Cependant pour que les résultats soient bien représentatifs, il convient de multiplier les phytomètres. On emploiera à cet effet des *"batteries"* composées d'un nombre conventionnel de plantes, six à dix. Comme membre de chaque batterie, il convient de choisir des plantes à moeurs et à allures semblables.

Pour l'étude d'un caractère, il faut faire usage de 3 à 5 espèces de plantes.

Lorsque les phytomètres sont des plantes inférieures, des cryptogames invasculaires (Lichens, Mousses) ou des plantes supérieures herbacées, surtout celles qui touffent, on les considère en communauté; leur unité de mesure est *le quadrat* d'un mètre de côté. Une fois ces phytomètres appareillés, l'on considère, pour déterminer le nombre et le lieu des stations, la nature des problèmes à résoudre. Il est de ces expériences qui sont parfaites en un seul climat. Mais lorsque les recherches sont comparatives, une échelle des divers climats est nécessaire.

Les montagnes sont idéales pour ces sortes d'étude pouvant offrir, de leurs bases à leurs sommets, une série complète de climats dans un minimum d'espace. Tout au bas, règnent les étangs, les marécages, les bas-fonds. Viennent ensuite les "prairies mixtes"; puis les "forêts de montagne", composées de ces conifères qui en font la beauté; à celles-ci succèdent les forêts de plus en plus rabougries qui caractérisent la "zône sub-alpine,". En avant de ces arbres écrasés contre le sol, aux branches désespérément insoufflées, il y a la "prairie alpine" qui va jusqu'au glacier du sommet. En somme, tous les climats qui se rencontrent sur un même méridien à des latitudes successives s'étagent sur les flancs des montagnes de quelqu'importance, au fur et à mesure que l'on s'élève en altitude. *Altitude et latitude se correspondent.* Les batteries ou les quadrats une fois en place, le problème qui doit retenir toute l'attention de l'expérimentateur est le mesurage des réponses qu'il faudra calculer sur le limbe de la feuille, la longueur et le nombre des entre-noeuds de la tige ou sur toute autre différence morphologique facilement appréciable. L'ensemble de ces mesures permettra d'indiquer en chiffres la rapidité de croissance de la plante, d'établir son coefficient de croissance. Plusieurs phénomènes concourent à ce développement; telles: la transpiration, la photosynthèse, l'absorption qui sont relativement faciles à mesurer; la respiration est plus difficile.

Les Zoometres

Pour apprécier les facteurs écologiques on peut se servir de zoomètres, quoique les animaux soient plus indépendants de l'influence du milieu, pouvant se déplacer à leur guise, cherchant leur nourriture où la flore abonde. Cependant la température les affecte, ainsi que la quantité et la qualité de la nourriture qu'ils prennent. Au point de vue des autres méthodes, ils sont:

1o *des indicateurs* faisant compétition aux animaux locaux;

2o *des transférés* indiquant, par leur état de santé, la valeur d'un habitat adjacent;

3o *des introduits* donnant la valeur des milieux plus lointains d'où ils viennent; tels sont nos animaux domestiques importés.

Une Application

La colonisation dans la province de Québec, hors de la vallée du Saint-Laurent, est oeuvre méritoire. M.M.H. Nagant, professeur à l'Institut Agricole d'Oka, dernièrement dans une solide conférence à la Société d'Histoire Naturelle de Montréal, en a rappelé les difficultés. (1) Ces difficultés sont telles qu'il faudrait, pour réussir, à nos cultivateurs possédés du patriotique courage de s'y aventurer, une formation en sciences agricoles qu'ils n'ont évidemment pas, ou des guides officiels, capables de remplir, auprès d'eux, le rôle d'ingénieurs agricoles.

Mais rien ne remplace, dans ces sortes d'entreprises, la formation personnelle pour vaincre les obstacles de l'arrivée, dans ces régions de par en haut, qu'infailliblement rencontre l'habitant des terrains-planches; formation personnelle qui laissera, à ceux de la famille demeurés à la maison, ces vieilles façons routinières de faire,—reçues de ancêtres et tenaces comme l'hérédité,—dont la pratique ne mène pas loin, même sur des terres travaillées depuis longtemps, et qui là-bas serient ineptes, sur des terres neuves.

A la base de la colonisation doit nécessairement se placer une formation scientifique convenable des futurs colons. Il ne suffit pas de quelques petits conseils donnés en passant, à bord du train qui conduit à Amos, entre deux pipées de tabac, ou condensés sur un feuillet énigmatique que personne ne lira, pour assurer le succès de cette nouvelle profession. La concession de la coupe du bois ne suffit pas, le don des instruments aratoires non plus; tout ce qu'on pourra imaginer d'encouragement matériels ne sauront pas suffire. Nos colons ont avant tout besoin de lumière. Il faut leur faire comprendre que la terre à eux confiée, n'a pas les mêmes qualités ni les mêmes défauts que celles qu'ils quittent. Les terres de la vallée du St-Laurent étaient riches, profondes, bien fixées. Les terres neuves sont souvent minces; il ne faudra pas déboiser complètement avant d'avoir arrêté, en y semant des plants convenables, cet humus de surface que les grandes pluies menacent; il faudra une rotation spéciale. Il y a le problème des engrais. Celui de l'écoulement des produits; le colon hier était aux portes des grandes villes, demain il sera à 500 milles. Ce n'est plus la même chose. Il y a le problème de l'alimentation du bétail, commandé par le problème plus englobant de la production en

(1) Henri Nagant: Géologie et resources agricoles. Cf. L'Actualité Economique, p. 25, mai 1927.

général: production des animaux eux-mêmes, production de leurs fourrages, production des légumes...

Ici, ressort l'utilité d'un minimum de connaisances précises des divers facteurs écologiques et de leurs influences respectives sur le rendement de terres encore certains endroits tout hérissés de souches. Les gelées y apparaîtront plus tôt à l'automne, le printemps y sera plus tardif; d'où acclimatation prudente de nos espèces végétales les plus résistantes au froid; aux autres espèces, il faudra, sans perdre de temps, substituer des variétés plus précoces, plus rustiques. Pour que les essais infructueux ne se multiplient pas de façon décourageante, il sera urgent, entre autres conditions de succès, que le colon se rende compte du coefficient physiologique du milieu où il s'installe; qu'il sache lire quelles réponses les semences feront au nouveau climat, non pas dans des instruments météorologiques compliqués dont les indications manqueront d'ailleurs de sensibilité et dérouteront par leur précision excessive, mais dans quelques phytomètres naturels: graminées sauvages ou échappés de culture. C'est alors que la formation sérieuse donnera son fruit, paiera.

D'instinct, le nouveau venu sans préparation ira voir comment ont monté les récoltes du voisin avant lui installé; voisin pas plus éclairé, pas plus en état de raisonner sa situation que celui qui le consulte. Pareille leçon sera rien moins que sûre; ces cultivateurs ne sachant pas analyser les causes de leurs succès ou insuccès, les effets d'un accident ou d'une chance passagère les dérouteront. Leçon qui se donnera, en tout cas, trop tard; ce n'est pas arrivé sur les lieux qu'il convient d'apprendre ce qu'il faut faire et comment il faut faire. Leçon qui n'enseignera que la routine en un lieu neuf où l'agriculture n'a pas encore de tradition; ces méthodes irraisonnées de cultiver ont pu donner des résultats sur les vieilles terres que le nouveau colon vient de quitter,—les experienécs, si mal conduites soient-elles, révèlent toujours quelque chose d'utile;—sur des terres inconnues et différentes, les pratiques routinières ne peuvent être que fatales, sans aucune chance de succès.

Au moment du départ de leur garçon pour le Nord, la famille se saigne pour accommoder celui qui s'en va; le père donnera un gros cent piastres; la mère, quelques bonnes couvertes de laine du pays, des ustensiles de ménage; les autres plus jeunes, de petits reins qui témoignent de l'affection à celui qui quitte. Mais ces manifestations d'un amour familial sont impuissantes et manquent de lumière.

Combien souvent ceux qui dirigent nos populations agricoles: députés, agronomes, journalistes, ne devraient-ils pas rappeler à ces cultivateurs dont les familles débordent, que nul cadeau n'est plus essentiel aux débutants en agriculture, qu'un bon cours dans quelqu'un de nos instituts agricoles, ne serait-ce que de six semaines; (2) que faire un tel cadeau à celui qui s'en va,—

(2) *L'Institut Agricole d'Oka*, La Trappe, comté des Deux-Montagnes, est tout spécialement outillé pour satisfaire aux exigences de ce groupe intéressant de la population agricole du Québec, avec ses divers Cours:

1.—*Cours agronomique*, de 4 ans, conduisant au baccalauréat en sciences agricoles.

2.—*Cours Moyen de deux ans*, destiné aux jeunes fils de cultivateurs qui n'ont pas la préparation nécessaire exigée pour le cours agronomique.

3.—*Cours Abrégés d'hiver de six semaines*. Ce cours ferait très bien pour les jeunes colons désirant entrer en affaire sous peu.

4.—*Cours des élèves libres* accordant toutes les facilités possibles.

cadeau qui ne coûtera pas cent piastres,—est dans la presque totalité des cas, non pas une libéralité, une friandise qu'on peut donner ou non à volonté, mais une stricte obligation.

L'application que je viens de faire aux jeunes colons, tendant à montrer la nécessité actuelle de s'instruire des découvertes de la science en agriculture pour réussir dans ce domaine, peut et doit également se faire à tous ceux qui débutent sur les terres. De toute nécessité, ces jeunes cultivateurs, que ne dévorera pas la ville, doivent adapter leurs méthodes de cultiver aux temps et aux lieux qu'ils traversent, s'ils veulent réussir. Les lieux sont parfois favorables pour certains, les temps demeurent difficiles. D'où obligation de s'instruire pour tous.

UNE LACUNE DE L'ENSEIGNEMENT SUPERIEUR AGRONOMIQUE*.

Maurice Lambilliotte,

Notre Manque de Culture Generale

S'il est un service qu'en toutes circonstances, on doive à ses amis, c'est bien celui de la vérité, même déplaisante.

Bien peu, je crois, me contrediront si j'avance, que les ingénieurs qui sortent de nos Instituts supérieurs d'agriculture, si écoutés qu'ils puissent être quant à leurs connaissances agronomiques, n'ont cependant, dans la grande famille universitaire, qu'une place tout-à-fait secondaire, font figure de parents pauvres.

De ce manque de prestige, la plupart d'entre nous n'ont pu manquer de ressentir déjà la cuisante humiliation.

Nous manquons de culture générale, c'est le grand reproche qu'on nous fait. Si l'on y réfléchit quelques instants, ce reproche est sérieux, car cette culture générale de l'esprit, celle que l'on peut appeler réellement supérieure, n'est rien moins que capitale dans l'existence.

Entre les membres d'une élite, elle crée un plan de rapprochement, un terrain d'entente, une sorte de commun langage, indispensable entre des êtres qui, sans cela, risqueraient de s'isoler chacun dans sa spécialisation ou dans son groupe, ne participant que par un plan inférieur à la vie commune.

D'un point de vue plus immédiat, mais qui touche d'avantage à ce manque de prestige que nous déplorons ici, il faut noter aussi, que c'est avant tout sur ce plan des connaissances générales, de la culture supérieure, à l'amplitude plus ou moins vaste de leur esprit que se jugent des hommes, que, dans l'ordre professionnel leurs pairs, seuls, peuvent décemment apprécier. D'ailleurs, cette spécialisation, ce langage proprement technique, si important

* Cet article est reproduit des "Annales de Gembloux," organe officiel de l'association des ingénieurs sortis de l'institution de ce nom.
Les considérations qui y sont faites à l'intention des diplômés de l'enseignement agricole supérieur de Belgique ne manqueront certainment pas non plus d'intéresser les techniciens agricoles de la province de Quebec; ils y trouveront plus d'un point de rapprochement entre leurs conditions ou besoins et ceux de leurs confrères de Belgique.

pendant toute une période, la période des études, parce qu'il requiert alors toute l'attention, voit son exclusivité fortement entamée, au contact des réalités avec lesquelles l'homme est aux prises. Tandis qu'en même temps grandit la nécessité de posséder des connaissances plus générales.

Cet élargissement de l'esprit, privilège d'une culture intellectuelle vaste et profonde, humaine enfin, nous élève. Elle dégage notre intelligence du fatras des trop immédiates contingences et l'amène à un merveilleux promontoire, d'où nous pouvans alors embrasser un plus large horizon, où, plus de faits et de notions nous apparaissent dans leur équilibre réel et leur naturelle harmonie.

D'un état d'esprit forcément étroit; parce que son objet même le limite, l'état d'esprit du spécialiste, cette culture générale forme le nécessaire contrepoids. A l'univers toujours déformé que conçoit le spécialiste en fonction de sa spécialité, elle oppose un univers plus vaste, où prennent place d'autres spécialités, où chacune se situe à son rang d'importance qui est toujours relative. Mieux même, elle seule, fait apparaître les rapports qui unissent entre elles diverses disciplines qui, s'ignorant, n'ont que trop tendance à se méconnaître. Elle seule aussi permet de contrebalancer le puéril orgueil qui rend tant de spécialistes insupportables. Du spécialiste, du technicien, elle fait avant tout un homme. Car c'est bien là, au fond, son centre et son essence, à cette culture générale: la connaissance de l'homme et de l'humain, aussi vaste, aussi profond qu'on puisse l'étendre.

Le service que l'on peut en attendre, ne vaut pas seulement dans son incidence morale, pour l'élevation de l'être. Le rendement le plus immédiat de l'individu, en dépend à son tour.

Plus que jamais, d'ailleurs, cette culture supérieure de l'individu devient une nécessité pour l'élite, un devoir aussi, dans un monde où tant d'événements sont en gestation, où tout est si bouleversé, que l'esprit se demande s'il se trouve au seuil d'une renaissance ou à la veille d'une définitive décadence.

C'est un impérieux devoir, devoir d'occidental et de civilisé, que de s'intéresser à d'autres problèmes que ceux de nos intérêts matériels et immédiats. Malgré nous, du fait de ce bouleversement général, nous engagés dans cette » mobilisation de l'intelligence » que signalait naguère l'un des plus profond philosophe politique de ce temps. Au temps de Miltiade et de Thémistocle, le serment de la jeunesse de la cité antique sauva l'Europe de l'Asie.

Beaucoup d'entre nous sont appelés ou peuvent l'être, à exercer à l'étranger leur profession. Une culture générale, la plus vaste possible, leur sera d'un immense appoint: culture historique, géographique, culture littéraire et à travers elle, c'est la culture psychologique et une culture de la sensibilité que nous concevons. Elle leur permettra de comprendre bien mieux, certains problèmes qui ne manqueront pas de s'offrir à leur intelligence et à leur action. Sans compter que le prestige que leur vaudra cette haute culture, rejaillira à travers eux, sur leur pays, doublant ainsi leur service.

* * *

Ce vœu et ce regret seraient tout platoniques, si nous n'indiquions quels excitants, quelles aides, cette recherche d'une plus ample culture de l'esprit pourrait et devrait rencontrer.

Nous sommes évidemment, touchant cette culture générale, désavantagés vis-à-vis de ceux qui étudient dans une grande ville, font partie d'une université, où excessive peut-être—et c'est parfait—mais vivante, bouillonnante, s'agite, se heurte, s'exalte, une vie intellectuelle intense qui imprime une marque profonde à ceux qui l'ont vécue.

Nous ne saurions trop encourager nos jeunes camarades à participer de toute l'ardeur de leur inexpérience et de leur enthousiasme vierge encore, à cette bataille des idées.

Qu'importe qu'ils se trompent! Nous préférons, quant à nous, de jeunes mais vigoureux et ardents sophistes, à de trop prudents jeunes gens, précoces vieillards qui redoutent la vie et ne lui apporteront pas grand'chose d'eux-mêmes.

Que nos étudiants lisent beaucoup. Qu'ils s'intéressent au mouvement des idées. Qu'une certaine politique du monde aussi, arrête leur esprit. Qu'ils discutent. C'est de leur âge et cela fait partie de ce qu'ils doivent apprendre pendant ces années, les plus fructueuses s'ils le veulent, de leur existence.

Mais à ce programme tout de même un peu anarchique, il faut un contrepoids, un excitant peut-être aussi. Et c'est ici que prend place une idée que beaucoup croyons-nous partageront avec nous.

Pourquoi ne créerait-on pas, à l'Institut, un cours de philosophie? Mais oui, non pas seulement un cours de logique, si précieux pourtant pour l'étude, pour la gymnastique de l'intelligence et la marche de la connaissance, mais un véritable cours de philosophie. A côté de ce cours qui devrait se poursuivre jusqu'au terme des études, des conférences, des cours libres de géographie humaine, de philosophie, de l'histoire, donneraient à tous un précieux aliment intellectuel, précieux surtout pour ceux qui devront, hors de Belgique, chercher une carrière.

Simples jalons que tout ceci évidemment. Nous avons voulu montrer l'énorme importance de cette culture que trop peu d'entre nous possèdent, et par quelles voies, pas bien ardues nous pourrions y accéder.

Peut-être y reviendrons-nous quelque jour avec plus de détails. La question est ouverte, en tous cas.

BOOK REVIEW

GRASS LAND, ITS MANAGEMENT AND IMPROVEMENT, by *R. G. Stapleton M.A.*, Professor of Agricultural Botany, University College of Wales, Aberystwyth, and Director of the Welsh Plant Breeding Station; and *J. A. Hanley, A.R.C.S., Ph.D.*, Chief Agricultural Advisory Officer and Lecturer in Agricultural Science, University of Bristol. (Oxford University Press, 25-27 Richmond Street West, Toronto, Canada.)

To those who have been under the necessity of furnishing information concerning management and improvement of grass lands the present volume will prove of real help as a reference text. The manner of dealing with the question of grass lands is both interesting and unique. Much of the information presented is also of such general application that the text should serve a useful purpose in most districts where the pasturing of animals presents economic problems.

The book is divided into fourteen chapters covering the following phases of the subject under discussion: (1) Types of British grass land: natural types (2) Types of British grass land: semi-natural types (3) The improvement of grass land: fundamental considerations (4) The mechanical treatment of grass land (5) The use of lime on grass land (6) Manuring of grazing land (7) Manuring of mowing land (8) Renovating grass land without ploughing (10) Ploughing and immediate reseeding (11) Temporary grass (12) The chief herbage plants (13) Sowing land down to grass (14) Seed mixtures.

Under each of the chapter titles an interestingly written general discussion is found. While few details are included of individual experiments the results of many such have been used in the discussion of the general principles derlying the management and improvement of grass land.

The author realizes that the improvement of grass lands in general has received less consideration at the hands of farmers than most other phases of agricultural endeavor. The object of the book appears to be to place before those interested, suggestions based on the most recently established facts, the adoption of which would be expected to be accompanied by substantial monetary returns.

In addition to the general information contained in the text a list of selected literature comprising one hundred and forty-three references is included. These references are selected mainly because of their ability to portray the more recent advances in the knowledge of the management and improvement of grass land.

While the whole problem of grass land improvement is still in its infancy the present volume by Stapledon and Hanley presents the matter under discussion in the most up-to-date and interesting style yet available to the reading public. To students of agrostology this publication will prove a decided asset. At the same time it will provide interesting reading for the person who desires to be well informed on agriculture in general.

G.P.McR.

CONCERNING THE C.S.T.A.

With this issue of *Scientific Agriculture,* the official organ of the Society enters upon a new volume and appears in a new style of cover, with a large increase in the number of pages, a single column type page and on a better quality of paper. This change was recommended at the Vancouver convention last June, and while the editorial policy of the magazine is not changed, the journal now conforms more closely to similar journals in other countries.

Members of the Society are urged to support their own magazine by submitting for publication articles dealing with any of the various branches of agriculture—animal husbandry, entomology, extension, plant pathology, education, dairying, economics, apiculture, etc. There is no intention to limit the pages of the journal to research and experimental work, although this opinion seems to prevail among many members of the Society.

NOTES AND NEWS

Under the auspices of the Quebec local branch, a banquet was held at Lake St. Joseph in honour of the election of Mr. L. P. Roy as President of the C.S.T.A. The guest of honour was Dr. J. H. Grisdale, Deputy Minister of Agriculture for Canada. There were about seventy-five present.

The International Banquet, held under the auspices of the Eastern Ontario local on July 28th, was the most largely attended event in the history of the Society. Three hundred guests were present and the number would have been much larger had the accommodation not been limited. Addresses were given by Hon. R. W. Dunlap, Assistant Secretary for Agriculture at Washington, President J. B. Reynolds of the Ontario Agricultural College, Mr. P. A. Francis of the British Ministry of Agriculture, and Mr. L. P. Roy, President of the C.S.T.A. The Chair was occupied by Mr. M. B. Davis, President of the Eastern Ontario branch. Among the many prominent men present, in addition to those named above, were the Honorable W. R. Motherwell, Minister of Agriculture for Canada, Dr. J. H. Grisdale, Deputy Minister; Hon. John S. Martin, Minister of Agriculture for Ontario and Mr. W. B. Roadhouse, Deputy Minister; Don Salvador Castello, Director of the Royal Spanish Poultry School at Arenys de Mars, Mohammed Askar Bey of Egypt, Rev. Father Leopold, Director of the Oka Agricultural Institute, Hon. Harry Lewis, President of the U.S. National Poultry Council and many others.

John Fixter, Chief Supervisor of Illustration Stations for the Dominion Department of Agriculture, died at Ottawa on August 9th, in his 68th year. With the exception of the period between 1906 and 1914, when he was Farm Superintendent at Macdonald College and on the staff of the Commission of Conservation, he had been in the service of the Dominion Experimental Farms System since 1887.

The Civil Service Commission at Ottawa is advertising for an Assistant Agrostologist ($2,040 to $2,520 per annum) for the Experimental Farm at Brandon, Man., a District Insect Pest or Plant Disease Inspector ($1,620 to $1920 per annum) for the Dominion Laboratory of Plant Pathology at Saskatoon, Sask., a Senior Laboratory Assistant ($1,440 to $1,740 per annum) for the Dominion Seed Branch at Ottawa, and for a Clerk, Grade 3 ($1,380 to $1,620) for the Cereal Division of the Central Experimental Farm at Ottawa. Application forms must reach the Civil Service Commission not later than September 15th.

Dr. B. T. Dickson, Professor of Plant Pathology at Macdonald College (McGill University) has been appointed Senior Mycologist to the Council for Scientific and Industrial Research for the Commonwealth of Australia. He will sail from Vancouver on October 19th, 1927.

Dr. Dickson has been on the staff of Macdonald College since his return from overseas in 1915, first as Assistant Professor of Biology (1915-1920), then as Professor of Botany (1920-1926) and, since April, 1926, as Professor of Plant Pathology. He has been a member of the Graduate Faculty of McGill University since 1922.

Dr. M. Cumming (O.A.C. '00) who has been Principal of the Nova Scotia Agricultural College since 1905, is now Director of Agricultural Marketing for Nova Scotia.

J. M. Trueman (Cornell '95) has been appointed Principal of the Nova Scotia Agricultural College. He was Professor of Animal Husbandry and Farm Management at that institution from 1913 until 1926 and for the past year has been Director of Agricultural Extension in Nova Scotia.

W. V. Longley (O.A.C. '11) has been appointed Director of Agricultural Extension and Professor of Farm Economics at the Nova Scotia Agricultural College.

J. K. King, (Macdonald '13) has resigned his position as District Sheep and Swine Promotor in New Brunswick, under the Dominion Live Stock Branch, to become Director of the Maritime Marketing Board, a new organization. He will continue to have his headquarters at Moncton, N. B.

Graham Anderson (Saskatchewan '24) is with the Livestock Co-operative Marketing Association at Moose Jaw, Sask.

J. S. Dash (Macdonald '13) has been appointed Director of Science and Agriculture for British Guiana, succeeding Sir John Harrison. His new address is Dept. of Science, Georgetown, British Guiana.

C. C. Macdougall (Macdonald '27) has been appointed District Representative at Sussex, N. B.

Dr. J. M. Swaine, Associate Dominion Entomologist, will represent the Society at the Centenary of Marcelin Berthelot, the eminent French Chemist, to be held in Paris, France, October 23rd to 26th, 1927.

C. J. Turcot (Montreal '24) has been appointed to the Tobacco Division of the Central Experimental Farm as a specialist in plant breeding.

G. F. H. Buckley (Alberta '20) has returned to the University of California to continue his studies towards the Ph. D. degree.

J. R. Weston (Manitoba '13) is field Supervisor at Provost, Alta., under the Provincial Department of Agriculture and not, as announced in the July issue, under the Soldier Settlement Board.

G. E. Sanders (O.A.C. '07) has resigned from the New York Insecticide Co. at Medina, N.Y., and is now with the Ansbacher Insecticide Co., 527 Fifth Avenue, New York.

J. H. Tremblay (Laval '17) Supervisor of Dominion Illustration Stations, is now at the Dominion Experimental Station, Kapuskasing, Ont. He is trying to organize a new branch of the C.S.T.A. for Northern Ontario.

R. R. McKibbin (Macdonald '23) has been appointed Lecturer in Chemistry at Macdonald College.

R. Schafheitlin (Macdonald '16) was married on August 17th, at Canning, N.S. to Kathleen Louise Eaton.

M. C. Jamieson (O.A.C. '22) is Advertising Manager of the World's Butter Review, Box 579, Edmonton, Alta.

E. G. Booth (Saskatchewan '21) is Extension Agronomist at the Agricultural College, Cass Co., N. Dak.

D. A. McCannel (Alberta '24) is Publicity Commissioner for the Alberta Dept. of Agriculture, Edmonton.

R. A. Derick (Macdonald '20) is now with the Cereal Division of the Central Experimental Farm, Ottawa.

The address of Dr. C. A. Zavitz, who recently retired as Professor of Field Husbandry at the O.A.C., is R.R. 2, Ilderton, Ont.

O. W. Lachaine (Macdonald '22)) is a District Plant Disease Inspector under the Dominion Dept. of Agriculture, with headquarters at the Ontario Agricultural College.

F. C. Paterson (O.A.C. '15) has been transferred as District Representative from Port Hope to Simcoe, Ont., and J. Y. Kellough (O.A.C. '25) has been appointed District Representative at Port Hope..

F. W. Walsh (O.A.C. '22) is now with the Colonization Department of the Canadian National Railways at Montreal.

A. S. Kyle, formerly Poultry Promoter with the Saskatchewan Dept. of Agriculture, is now the California agent for the Petersime Incubator. His address is 3946 Dalton Ave., Los Angeles, Cal.

E. E. Reilly (O.A.C. '16) is with the Bell Telephone Company at Montreal.

T. O. Clark (O.A.C. '12) is Manager of the Cornwall Dairy Products, Ltd., Cornwall, Ont.

C. K. Johns (Alberta '25) has been appointed Assistant Agricultural Bacteriologist at the Central Experimental Farm, Ottawa.

AT THE CENTRAL OFFICE.

The General Secretary has prepared a C.S.T.A. handbook for distribution to members and prospective members. It is now being printed and will be in the mails about September 15th. It is intended to furnish complete information regarding the Society's past history and present activities, and includes the revised constitution and by-laws, personnel of committees and other information. Members will probably find it useful for reference purposes.

Those members who are familiar with the difficulties of the Society at the central office will be glad to know that a combined clerical assistant and stenographer was appointed on September 1st. It is hoped that the increased efficiency at headquarters, as a result of this appointment, will more than justify this new expenditure which had become absolutely necessary.

The General Secretary is removing from the membership list the names of all those members whose fees for last year (1926-27) have not been paid, and will carry on a membership campaign among recent graduates so that the total membership may be maintained at approximately 1,000. Members of the Society who know the names and addresses of prospective members should send them to the General Secretary now.

If *Scientific Agriculture* is to be maintained in its present size, members who are in a position to contribute articles must do so. It is necessary that each issue should contain between 80 and 100 pages, in order that the style of binding used in this issue may be adopted permanently. For the time being publication within three months after receipt of manuscript can be promised and 100 reprints will be furnished free if desired.

Articles for publication should always be typewritten (double spaced), and submitted in duplicate. Too much tabular matter and too many illustrations should be avoided. A summary of every article, by the author, should be incorporated in the article to facilitate reviewing and abstracting. Proofs will always be submitted to the author before publication.

It is estimated that the extra cost of increasing the size of the magazine is about $4,000 per year, and an appeal is being made to the Dominion and Provincial Departments of Agriculture, the National Research Council and the Agricultural Colleges for financial assistance in an effort to maintain a Canadian journal of this kind. Unless assistance can be obtained in this way, the size will have to be greatly reduced, but at the time of writing the response to the appeal is highly gratifying.

It is the intention of the General Secretary to reserve a section of the magazine for the publication of notes and news, correspondence, and similar material and more space will be given to this than has been the case heretofore. To assist in carrying out this policy, members are particularly invited to notify the General Secretary promptly of any change in their position or

address, and to send in any items of news which might be of interest to the membership body.

Local branches are now arranging their programmes for the coming winter. The General Secretary expects to attend the first meeting of the Western Ontario branch at Toronto on September 9th and of the Niagara Peninsula branch at Grimsby or St. Catharines the following day.

An effort is being made to organize a branch of the Society in Great Britain with headquarters at London, and another branch in Northern Ontario, with headquarters at Kapuskasing. If the organization work is successfully completed the total number of branches will be increased to eighteen. A. R. Milne, formerly Secretary of the Niagara Peninsula branch and now with the C.N.R. Colonization Department in England, is directing the organization of the new local at London, and Harry Tremblay at the Dominion Experimental Station at Kapuskasing is organizing the Northern Ontario local.

The finances of the Society are not in as good condition now as they were at the time of the Convention in June, due to the fact that comparatively few renewal membership fees were paid during the summer months. It will be appreciated if members who have not already received their membership cards for 1927-28, will send their $5.00 now to their local secretary or to the central office. Although the cost of printing *Scientific Agriculture* has been increased by approximately $4.00 per member, it is not intended that annual fees will have to be raised. Members will continue to receive the journal as part of their membership privileges.

The report of the Committee on the Co-ordination of Agricultural Policy, presented by Dean E. A. Howes at the Vancouver Convention, is now being printed and will be mailed to every member of the Society during the month of September. It will also be mailed to members of the Dominion House of Commons and Senate and to any others who might be expected to be interested.

The tentative dates for the 1928 Convention at Quebec City are June 5th to 9th. Members of the Quebec local Executive will meet in September and will appoint committees on Entertainment, Programme, Publicity and Reception. Members of each of the four branches in the Province of Quebec will be appointed to these Committees and will be expected to meet in Montreal during the Provincial Apple Show in November.

It is intended to hold the next Convention under the group system, except for business sessions and social features. Probably four groups of lectures will be arranged and it is possible that out of these group meetings, special groups of the Society will be formed, similar to the horticultural group which was organized at Vancouver last June.